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ABSTRACT

This instructional manual contains 20 learning activity packets for use in a workshop on lasers and fiber optics. The lessons cover the following topics: what a laser; coherent light; setting up the laser; characteristics of the laser beam; scattering of light; laser beam divergence, intensity, color, ophthalmology, and reflections; directivity of laser beam communication systems; simultaneous amplitude and polarization; measurement of glass thickness and liquid level; laser beam intensity control by polarizers; splitting the laser beam by parallel glass and by prism; light pipes and fiber optics; laser amplitude modulated communcation; and simultaneous amplitude and polarization modulation of the laser beam. Each learning activity packet lists prerequisites, purpose, and competencies to be developed and provides information sheets, illustrations, and learning activities. (KC)

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LASER & FIBER OPTICS:

Instructional Manual

Writer: Dr. Luvern R. Eickhoff

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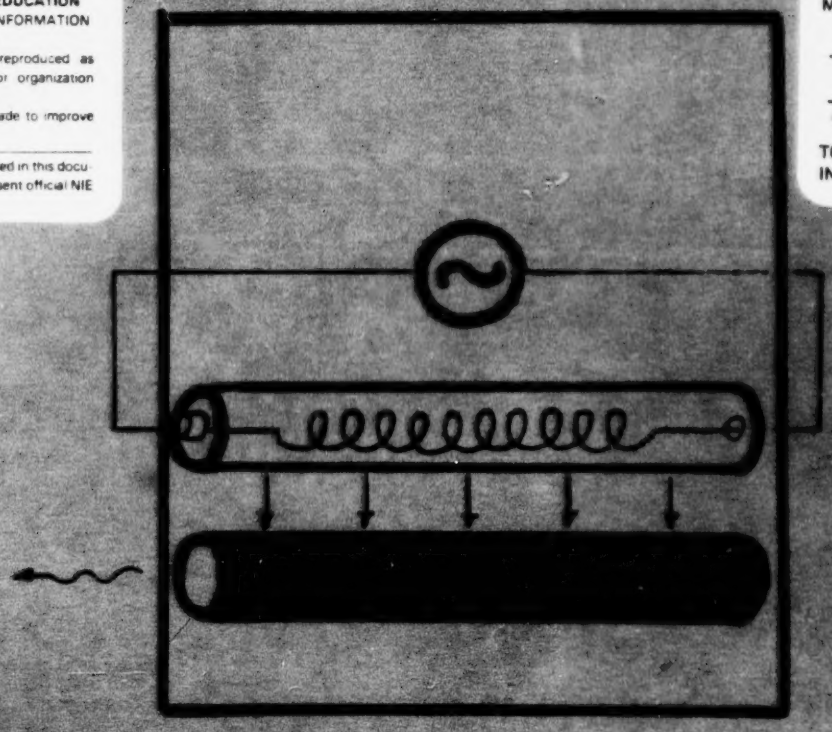

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Instructional Manual
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Laser and Fiber Optics
Instructional Manual

Titles of Learning Activity Packets;
High Technology Mobile Laboratory

Unit #	Title
1	What is a Laser?
2	Coherent Light
3	Setting Up the Laser
4	Characteristics of the laser Beam
5	Scattering of Light
6	Laser Beam Divergence
7	Laser Beam Intensity
8	Laser Beam Color
9	Laser Ophtalmology
10	Laser Beam Reflections
11	Directivity of Laser Beam Communication System
12	Simultaneous Amplitude & Polarization
13	Measurement of Glass Thickness
14	Meausrement of Liquid Level
15	Laser Beam Intensity Control by Polarizers
16	Splitting the Laser Beam by Parallel Glass
17	Splitting the Laser Beam by Prism
18	Light Pipes and Fiber Optics
19	Laser Amplitude Modulated Communication
20	Simultaneous Amplitude and Polarization Modulation of the Laser Beam

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HIGH TECHNOLOGY MOBILE LABORATORY

Learning Activity Packet

MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 1

LAP TITLE: Setting up the Laser

PREREQUISITE LAP (S): None

LAP PURPOSE: To know the operating instructions and procedures in using the laser.

COMPETENCIES TO BE DEVELOPED:

1. To learn that the laser should be pointed toward a wall or other dull surface.
2. To never look directly into the laser beam!!
3. To never leave the laser unattended.
4. To never use water or other liquids on the operating laser.
5. To never aim the laser at a person.
6. To plug the line cord and coaxial cables into the respective jacks.
7. To turn the power switch on so as to allow for a duration of war-up before use.

SETTING UP THE LASER

READ THIS SECTION CAREFULLY BEFORE OPERATING THE LASER !!!

ALSO READ THE METEROLOGIC MANUAL THOROUGHLY BEFORE PROCEEDING FURTHER !!!

The manufacturer of the laser supplied with the LDS10 has taken precautions to meet the latest safety standards and the system is designed to be safe when operated as directed.

NEVER LOOK DIRECTLY INTO THE LASER BEAM!!!

DO NOT LEAVE THE LASER ON WHEN UNATTENDED !!!

NEVER USE WATER OR OTHER LIQUIDS ON THE OPERATING LASER !

NEVER, NEVER, NEVER AIM THE LASER AT A PERSON OR ANIMAL !!!

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Learning Activity Packet

MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 2

LAP TITLE: What is a Laser

PREREQUISITE LAP (S): 1

LAP PURPOSE: To visualize the laser as an optical device producing an optical light output signal.

COMPETENCIES TO BE DEVELOPED:

1. To know the different laser types: e.g. ruby, semi-conductor, gas to name a few.
2. To know the basic elements of the laser: amplifier, selective feedback network, and power supply.

INTRODUCTION

Since its invention in 1960 by a team of scientists at Hughes Aircraft Corporation, the Laser has been one of the most talked about of any recent scientific achievements. During the relatively few years since its developement , the laser has found a myriad of applications ranging from precision machining of exotic metal alloys and eye surgery to three dimensional holography and even inexpensive home video television players for pre-recorded discs.

The LDS10 Laser Demonstration System is designed to illustrate many of the basic laser applications and their practical uses. This instruction manual has been prepared and is designed to effectively present both the technical and practical aspects of modern laser technology. This manual contains over thirty experiments which use the LDS10 helium-neon laser, the amplifier/modulator and the receiver demodulator, as well as the wide assortment of optical components included with the trainer.

THE LASER AS A COMMUNICATIONS LINK

The LDS10 has several additional circuits to those shown in the printed manual that permit a wide variety of communications via tone and voice. This capability means that the light can be traced with sound !

To make it all happen, all that is required is to plug the laser into the two color front panel and then to turn on the key lock circuit breaker. Next the Receiver portion of the unit should be plugged into 120 vac. The receiver uses a sensitive photo/solar cell to receive the modulated laser light and turn it into a tone or voice reception.

Since this is a sensitive amplifier photo cell combination, there will always be background hum present to varying degrees due to the ambient light in the room. Fluorescent light in particular can cause a distinctive hum.To eliminate this background hum, turn out as many lights as feasible ! Even then the high gain amplifier will hum if the signal it receives is weak or non-existent. But the receiver sensitivity really makes communication possible and fun,so a little hum is all part of the game.

Increased volume comes from turning the knob clockwise. It is good practice to use the tone to setup and locate the light beam inside the grommet and hitting a sensitive spot on the photocell before plugging in the microphone and attempting voice communication.

To review : With the receiver volume turned fully clockwise, a definite audio tone should be heard from the receiver speaker. Reposition the receiver carefully for the loudest tone. Then plug in the microphone to the front panel jack, being careful not to disturb the laser or receiver positions. Hold the microphone close and speak into it. Your voice should be heard from the receiver speaker. If a feedback squeal occurs, reduce the volume control at either the receiver or the front panel.

Try increasing the distance between the receiver and the laser by moving the receiver some distance away from the microphone modulated laser. Remember that the background noise can be a problem if too many bright lights are on in the room. Turn them off if it is necessary for clear reception with minimum hum.

Once you are familiar with straight line communication, try variations such as bouncing off of mirrors or passing the laser light through lenses such as is suggested in the following detailed experiments.

THE LASER AND COHERENT LIGHT : AN EXPLANATION

What is a Laser ?

While it is possible to delve into the advanced mathematics and physics quantum theory for the advanced explanation of laser action, this is not necessary for a good understanding of laser operation.
An excellent way to understand the laser is to visualize it as an optical oscillator producing an optical light output signal as compared to an electronic oscillator which generates an electrical output signal. Each contains the same basic elements : an amplifier, a selective feedback network and the necessary power supply.

There are a number of different laser types such as ruby, semi-conductor, and gas, to name just a few. We will be using a helium- neon gas laser manufactured by Metrologic. The enclosed manual authored by that company provides more detail on the laser and similar or other applications to those described in this experiment manual.

The Helium-Neon Laser:

As shown in the figure, the helium-neon laser consists of a tube filled with a mixture of helium and neon gases that is sealed tightly from the atmosphere. Mirrors are incorporated into both ends of the tube of which one is 100% reflective and the other is partially reflective so that some amount of light can pass through it.

When the operating voltage is applied to the helium-neon laser, an electrical discharge occurs within the tube similar to that in a neon sign tube. This electrical discharge causes a large number of helium atoms to be elevated to a higher energy state. These higher energy helium atoms then transfer part of their energy to the neon atoms , causing them to also be elevated to a high energy state. This effect is shown in the figure.

After a short period of time, the elevated neon atoms drop down to a lower energy state. In so doing the neon atoms release the energy they had gained previously in the form of light energy of a specific frequency (wavelength). In the case of the LDS10 laser, this wavelength is 633 nanometers,(6328 angstoms).

As this generated light energy propagates along the laser tube, a good part of it is lost through the walls of the glass tube, while the rest travels along the axis of the tube. This light energy strikes additional energy elevated atoms, thus producing still more light energy.

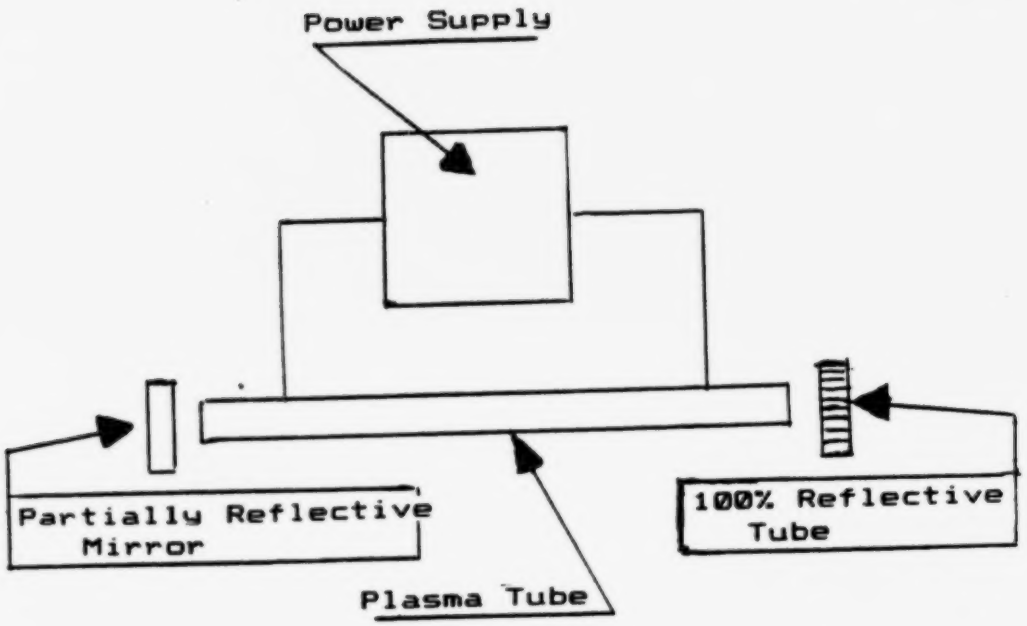

Power Supply
Partially Reflective Mirror
100% Reflective Tube
Plasma Tube

Figure 1

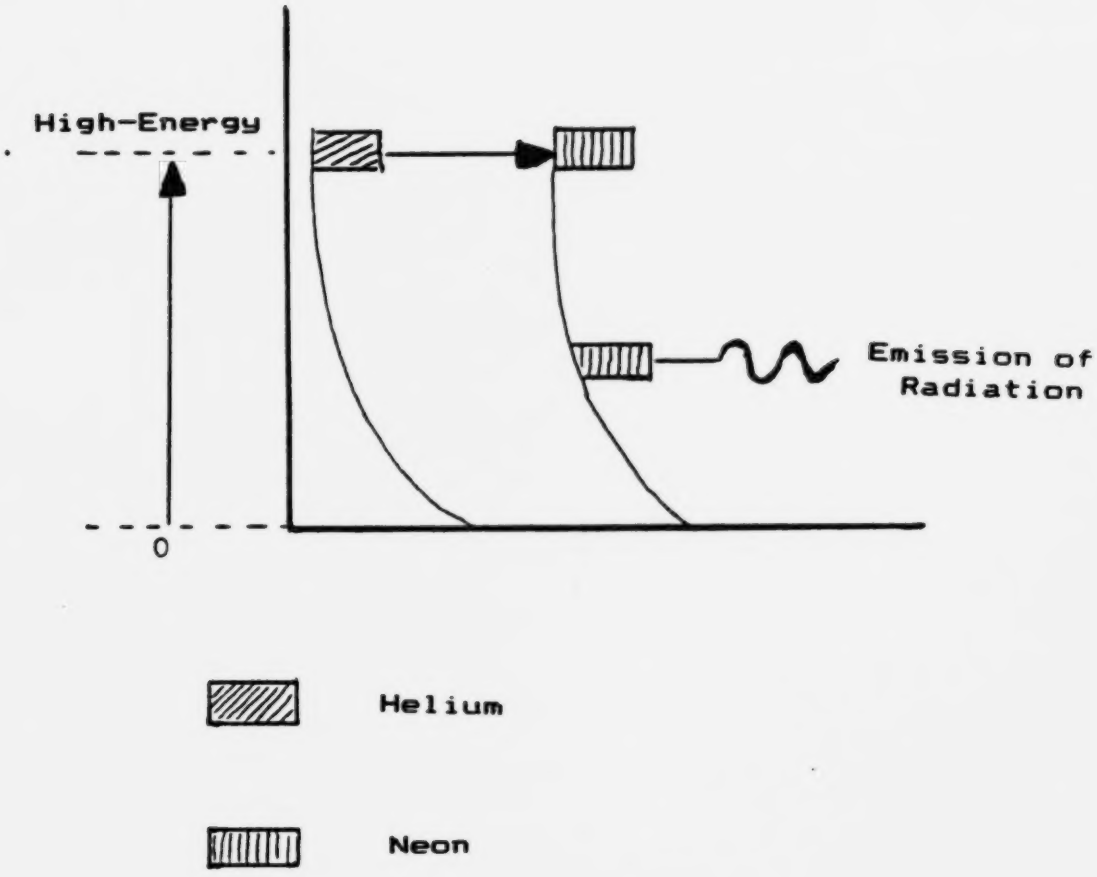


Figure 2

The light energy traveling along this length of tube will strike one of the end mirrors and then be reflected back down the tube where it will strike the mirror at the opposite end of the tube. The net result of this is that the light will continue to bounce back and forth between the mirrors on each end of the tube. At each "pass" along the tube, the light energy increases until it is great enough to pass through the partially transparent end mirror ... producing the visible laser beam.

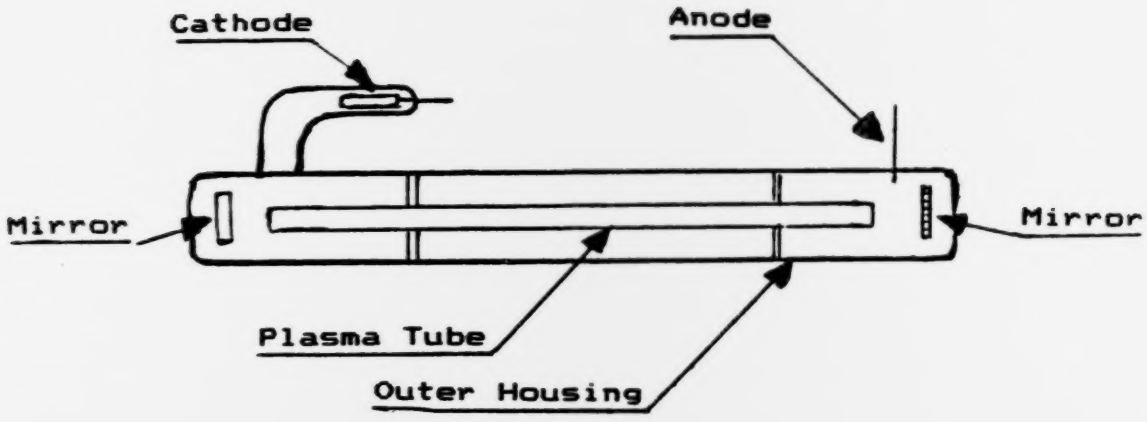
This phenomena is how the laser got its name:Light Amplification by Simulated Emission of Radiation. Light Amplification within the laser tube is the result of electrical simulation of the neon and helium atoms.

From this review of the operation of the laser, it can readily be seen that it does indeed use the same components as an electronic oscillator. Both the laser (optical oscillator) and the electronic oscillator use an amplifier, a feedback path and a power supply. In the case of the laser, the amplifier is the energy elevated (excited) neon and helium gases within the laser tube and the selective feedback system is the two end mirrors in conjunction with the energized laser tube gases. The radio frequency oscillator (electronic) employs a vacuum tube or transistor as the oscillator-amplifier and an inductance capacitance combination for the selective feedback system.

Other Laser Types:
While we are primarily concerned with the helium-neon laser, there are many other types of lasers.

THE LASER TUBE

The next figure is a diagrammatic view of the helium-neon laser supplied with the LDS10 laser. The laser tube is a completely self-contained assembly , consisting of the amplifier section, the end mirrors, the gas reservoir and the electrodes.
The amplifier section, which contains the actual lasing action, consists of a precision bore capillary tube which is filled with the proper mixture of helium and neon gases. The larger gas envelope surrounding the inner capillary tube holds a reservoir of gases to extend the operating life of the laser. An additional function of this larger tube is to support the precision aligned end mirrors.


Cathode
Anode
Mirror
Mirror
Plasma Tube
Outer Housing

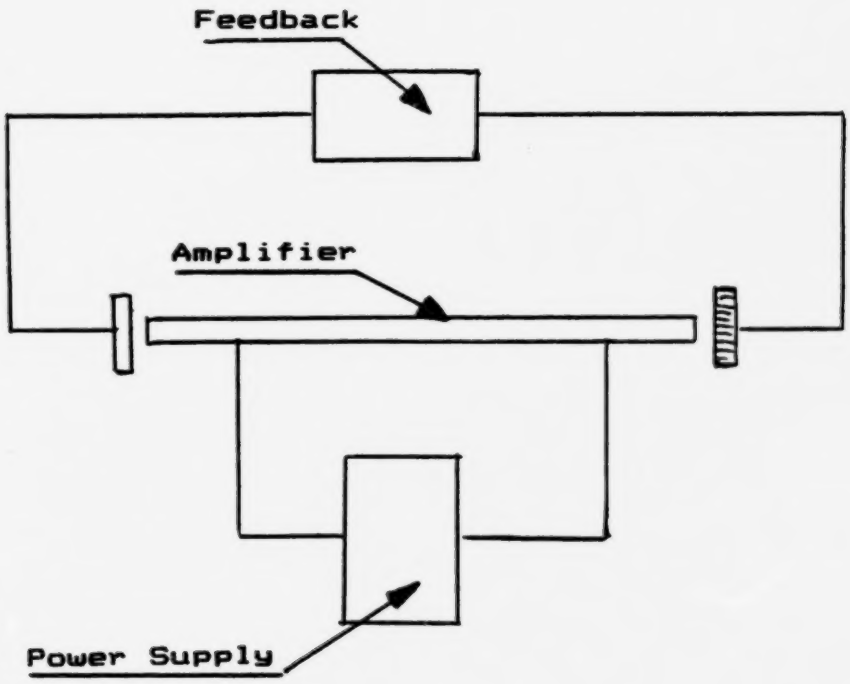


Figure 3

The Ruby Laser:

The original laser used a synthetic ruby rod as the lasing material. The basic operation of the ruby laser is similar to the gas laser...atoms are stimulated to an elevated state, from which they drop to a lower level, releasing light energy as they do so. The ruby rod is fitted with end mirrors which provide the same function (a selective feedback system) as in the gas laser.

Unlike the gas laser which uses an electrical discharge to elevate its atoms to a high energy state,the ruby laser is stimulated by a flash tube which provides an intense burst of white light energy. Thus the atoms within the ruby laser are optically pumped to a higher energy state, while the gas laser's atoms are pumped to the higher energy state by an electrical discharge.

The ruby laser produces a pulsed beam output for each light burst from the flash tube, while the gas laser produces a continuous output beam. For this reason, the gas laser is more applicable for a wide variety of applications such as wide-band communication and laser holography, to name a few. The principal applications of the ruby laser are in areas where very high power levels are required, such as in the cutting and machining of exotic materials, etc.

Semiconductor Lasers:

The semiconductor laser represents the third general class of lasers. Unlike the gas and ruby lasers, the semiconductor laser produces lasing action by interaction of electric charges at the junction of dissimilar semiconductor materials. Due to the limited power level of semiconductor lasers, they have not found wide applications except as the source for laser light in the newest generation of fiber-optic communications, an application that may indeeed outshine all the other more powerful lasers !

Miscellaneous Laser Types:

In addition to the major laser types described previously, there have been developed a number of lasers employing liquid dyes...one type using a familiar household detergent as the lasing medium. Other recently discovered laser materials include certain types of glass, plastic....and even paper.

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Learning Activity Packet

MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 3

LAP TITLE: Coherent Light

PREREQUISITE LAP (S): 1 & 2

LAP PURPOSE: To understand the most important simple characteristics of the laser, coherent light.

COMPETENCIES TO BE DEVELOPED:

1. To understand the significance of directionality, intensity, monochromaticity, and coherence.
2. To understand the nature of coherent light to that of natural light.

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COHERENT LIGHT:

The most important single characteristic of this laser, the LDS10, is that it produces a beam of coherent light. This coherent light differs from light as we know it in these unique ways:

Directionality

Intensity

Monochromaticity

Coherence

It is these characteristics of the laser produced coherent light that makes it so useful in a wide variety of applications.

In order to understand the nature of coherent light, let us first examine "ordinary" light which is diagrammed in the figure. Notice that the light waves do not start and stop at one given point in time....in effect, they are all jumbled. The reason for this is that light as we commonly see it is caused by electrons dropping down from a high energy state to a low energy state in a random manner...emitting light energy as they do so. On the other hand, as shown in the lower figure, coherent light results when all of the light energy waves start and stop in step at the same time. As such, they are said to be in phase

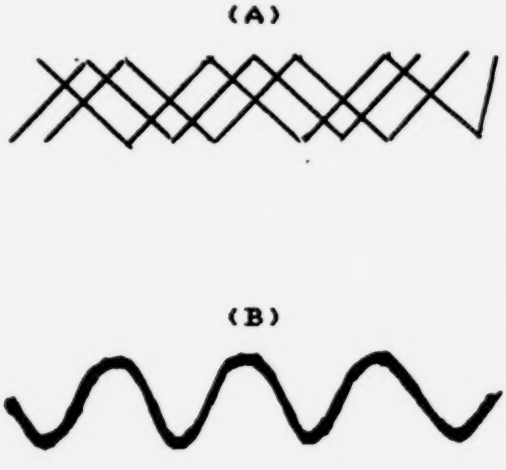


Fig.4

CHARACTERISTICS OF THE LASER BEAM

1. Intensity

2. Coherence

3. Monochromaticity

The extreme intensity of the laser beam (brightness) is due to the fact that all of the laser energy is confined to the very small diameter of the laser beam. While the average power of the beam is relatively low, all of this energy is confined within a very small area. In addition, all of the emmited light is at a single frequency(wavelength); this also contributes to the high intensity of the laser beam

The coherence of the laser beam is a result of the selective feedback system established by the two end mirrors on the laser tube. This effect may be likened to a very selective electrical filter whose output is a very pure electrical sine wave signal (no harmonics or distortion).

The monochromatic (single color) of the laser beam is also a result of the selective feedback provided by the laser tube end mirrors and also the narrow frequency bandpass of the amplifier: (excited helium and neon atoms). These factors result in the purity of the emitted laser beam being better than one part in 10 to the fifteenth.(1015).

DEMONSTRATION NUMBER TWO - MONOCHROMATICITY

INTRODUCTION

This demonstration will illustrate the monochromaticity (single-color) of the laser beam.

Components Required:

LDS 10 Laser

Prism

Setup

Be sure the laser is setup and mounted to its support on the side of the laser cabinent, as well as being turned ON.

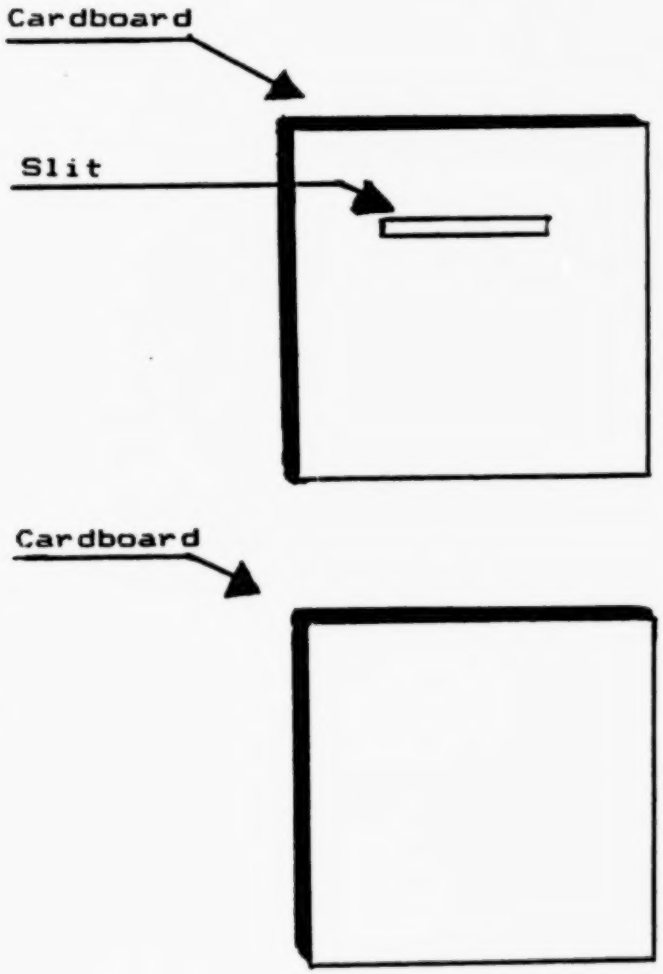
As is shown by the figure, cut a slit 1/2" x 1/2" in the center of one of two pieces of cardboard. Place the prepared cardboard in front of either sunlight or an incandescent bulb. Orient the prism in front of the slit so that the characteristic spectral "rainbow" is projected on the second unslit cardboard as shown in the next figure.

The use of the prism is to break up the white light which strikes it into its individual spectral wavelengths (colors).

From this it can be seen that light emitted by the light bulb (or sun) consists not of a single wavelength (color) but rather, of a wide range of wavelengths. Thus we have seen that this type of light source is not monochromatic.

Now energize the laser using all the precautions that were given previously. Orient the prism in front of the laser beam so that an image is projected onto the cardboard. Note that there is only a single color present (that of the original laser beam) which is thus produced by the prism. From this demonstration we can see that the laser beam is truly moncchromatic as only a single color is produced even when the light is passed through a prism.

Fig.8



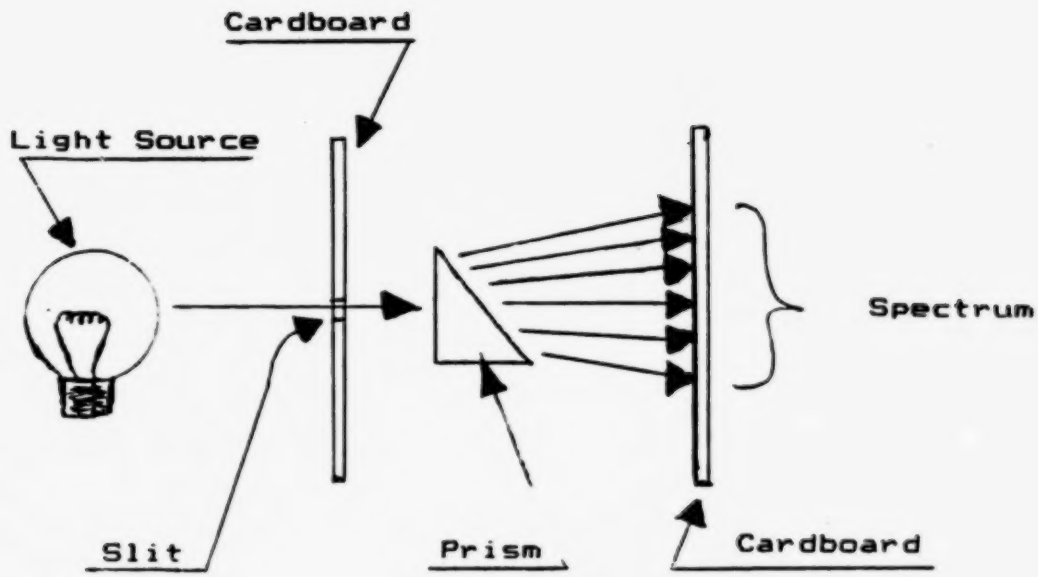


Fig.9

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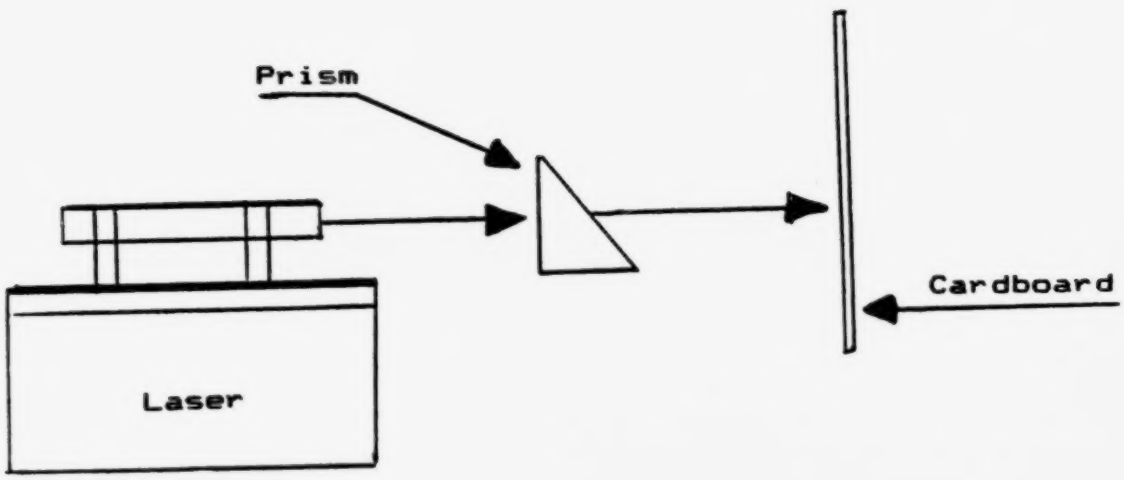

Fig.10

26

Discussion:

From this demonstration, we have proved that unlike light from such a source as an incandescent light bulb or the sun which contains a number of different wavelengths (colors), the laser produces a light output that is a single wavelength (color).

The monochromatic nature of the light output from the laser makes it extremely useful in many areas including "lensless" photography, holography, and areas of precise measurement.

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Learning Activity Packet

MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 4

LAP TITLE: Characteristics of the Laser Beam

PREREQUISITE LAP (S): 1, 2 & 3

LAP PURPOSE: To understand the characteristics of the laser beam in terms of intensity, coherence and monochromaticity.

COMPETENCIES TO BE DEVELOPED:

1. To know and understand the characteristics of the laser beam, i.e., intensity, coherenc,e and monochromaticity.

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WHAT IS A LASER?

The term "laser" is an acronym. It stands for "Light Amplification by Stimulated Emission of Radiation". Thus the laser is a device which produces and amplifies light. The mechanism by which this is accomplished, stimulated emission, was postulated by Einstein in 1917 but has only recently been applied. The light which the laser produces is unique, for it is characterized by properties which are very desirable but almost impossible to obtain by any means other than the laser.

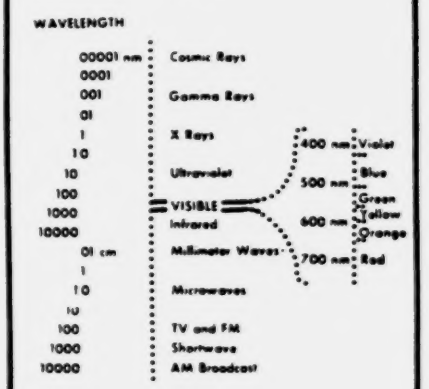
To gain a better understanding of what a laser is and what it can do, we shall start with a short review of some of the phenomena involved in laser action. A good subject with which to start is light.

A. Light

Light is a form of electromagnetic energy. It occupies that portion of the electromagnetic spectrum with which man first dealt because it was visible to the human eye. Originally the term "light" included only the visible frequencies. About 1800, however, the British-German astronomer, W. Herschel, placed a thermometer just beyond the blue portion of a spectrum produced by a prism using sunlight and found its temperature was raised. Later, invisible light was found on the other side of the visible spectrum. Thus it was that frequencies outside the visible range were lumped with the visible frequencies under the term light.

Later, when X-rays, radio waves, and other discoveries were made, light was found to be part of a spectrum of electromagnetic radiations. The distinction between the various radiations is primarily energy which is proportional to frequency. Light is considered to be that portion of the electromagnetic spectrum having wavelengths between 100 and 10,000 nanometers (nm = 10^{-9} meters) as shown in Figure 1.

Figure 1



ELECTROMAGNETIC SPECTRUM

From a classical point of view, electromagnetic radiations simultaneously display two seemingly contradictory properties. Electromagnetic radiations

1. Propagate through space as waves; and
2. Possess a definite particulate nature

since a discrete energy and momentum are associated with them.

Each of these properties is important to the complete understanding of the behavior of all electromagnetic radiation. Both properties are combined in the current concept of light as described by quantum mechanics.

Frequently, for aid in visualizing wave behavior, light is said to move in much the same fashion as waves on a body of water. While this is not entirely true, certain characteristics are common to both types of wave motions.

The fact that a definite energy is associated with the radiation is often considered a particulate property. It is therefore difficult to visualize electromagnetic radiations as continuous waves, propagating continuously through space. One

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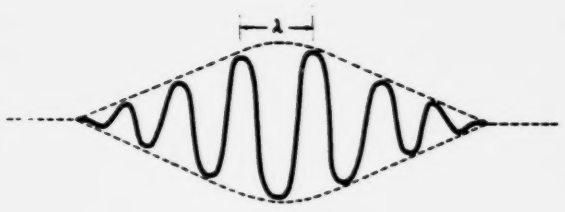
means of partially relieving this conceptual difficulty is thinking of the radiations as consisting of a limited "wave packet" which we call a "photon" (See Figure 2). The packet or photon is thought to move through space, thus satisfying a human need to visualize what truly cannot be visualized.

B. Electron Energy Levels

Light can be produced by atomic processes, and it is these processes which are responsible for the generation of laser light. Let's look first at atomic energy levels and then see how changes in these energy levels can lead to the production of laser light.

Figure 2



REPRESENTATION OF PHOTON

A number of simplifications can be made regarding the concept of the atom. We can assume, for purposes of this discussion, that the atom consists of a small dense nucleus and one or more electrons in motion about the nucleus.

The relationship between the electrons and the nucleus is described in terms of energy levels. Quantum mechanics predict that these energy levels are discrete. A simplified energy level diagram for a one electron atom is shown in Figure 3.

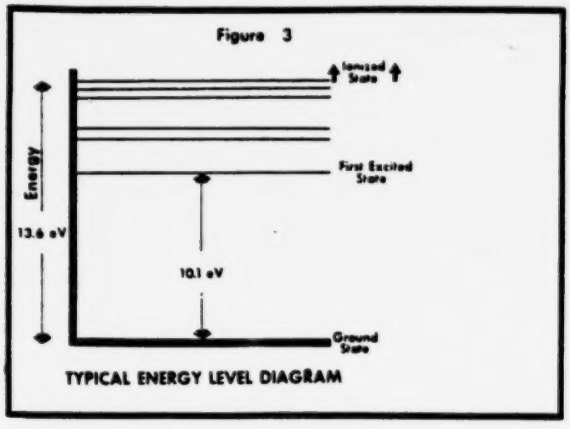
C. Radiative Transitions

The electrons normally occupy the lowest available energy levels. When this is the case, the atom is said to be in its ground state. However, electrons can occupy higher energy levels, leaving some of the lower levels vacant. The electrons change from one energy level to another by the absorption or emission of energy. One of the ways in which an atom can change its energy state is through what is called a radiative transition.

There are three types of radiative transitions. Two of these, absorption and spontaneous emission, are quite familiar, but the third, stimulated emission, is relatively unfamiliar. It is this third type of radiative transition that forms the basis for laser action. Each form of transition is described below.

1. Absorption. An electron can absorb energy from a variety of external sources. From the point of view of laser action, two modes of supplying energy to the electrons are of prime importance. The first of these is the transfer of all of the energy of a photon to an orbital electron. The increase in the energy of the electron causes it to "jump" to a higher energy level; the atom is then said to be in an "excited" state. It is important to note that an electron accepts only the precise amount of energy that will move it from one allowable energy level to another. Hence only those photons of the energy or wavelength acceptable to the electron will be absorbed.

Figure 3



TYPICAL ENERGY LEVEL DIAGRAM

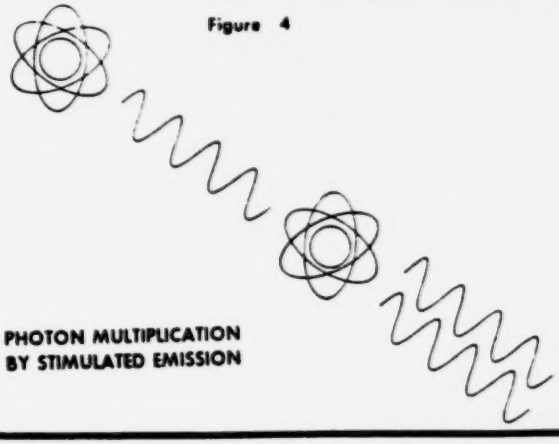
The second means often used to excite electronics is an electrical discharge. In this technique the energy is supplied by collisions with electrons accelerated by the electric field. The result of either type of excitation is that through the absorption of energy, an electron has been placed in a higher energy level than that in which it had been residing, and the atom of which it is a part is also said to be excited.

2. Spontaneous Emission. The entire atomic structure tends to exist in the lowest energy state possible. An excited electron in a higher energy level will thus attempt to "de-excite" itself by any of several means. Some of the energy may be converted to heat. Another means of de-excitation is the spontaneous emission of a photon. The photon released by an atom as it is de-excited will have a total energy exactly equal to the difference in energy between the excited and lower energy levels. This release of a photon is called spontaneous emission. One example of spontaneous emission (and absorption) is seen in phosphorescent materials. The atoms are excited by photons of appropriate energy from the sun or a lamp. Later, in the dark, they de-excite themselves by spontaneously emitting photons of visible light. A second example is the common neon sign. Atoms of neon are excited by an electrical discharge through the tube. They de-excite themselves by the emission of photons of visible light. Note that in both of these examples the exciting force is not of a unique energy, so that the electrons may be excited to any one of several energy levels. The photons released in de-excitation may have any of these several discrete frequencies. If enough discrete frequencies are present in the appropriate distribution the emission may appear to the eye as "white" light.

Now, let us look at the third, and probably the least familiar, type of radiative transition.

3. Stimulated Emission. In 1917 Einstein postulated that a photon released from an excited atom could, upon interacting with a second, similarly excited atom, trigger the second atom into de-exciting itself with the release of a photon. The photon released by the second atom would be identical in frequency, energy, direction, and phase with the triggering photon, AND the triggering photon would continue on its way, unchanged. Where there was one, now there are two. This is illustrated in Figure 4. These two photons could then proceed to trigger more atoms through stimulated emission.

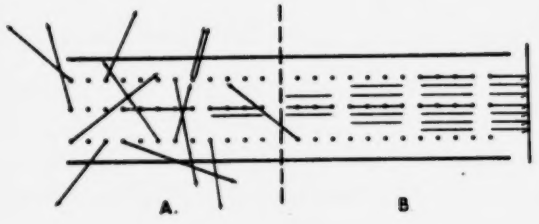
Figure 4



PHOTON MULTIPLICATION BY STIMULATED EMISSION

If an appropriate medium contains a great many excited atoms and de-excitation occurs only by spontaneous emission, the light output will be random and approximately equal in all directions as shown in Figure 5A. The process of stimulated emission however, can cause an amplification of the number of photons traveling in a particular direction--a photon cascade--as illustrated in Figure 5B. A preferential direction is established by placing mirrors at the end of an optical cavity. Photons not normal (perpendicular) to the mirrors will escape. Thus the number of photons traveling along the axis of the two mirrors increases greatly and light amplification by the stimulated emission of radiation occurs.

Figure 5



PHOTON CASCADE

D. Population Inversion. Practically speaking, the process of stimulated emission will not produce a very efficient or even noticeable amplification

of light unless a condition called "population inversion" occurs. If only two of several million atoms are in an excited state, the chances of stimulated emission occurring are infinitely small. The greater the percentage of atoms in an excited state, the greater the probability of stimulated emission. In the normal state of matter, the population of electrons will be such that most of the electrons reside in the ground or lowest energy levels, leaving the upper levels somewhat depopulated. When electrons are excited and fill these upper levels to the extent that there are more atoms excited than not excited, the population is said to be inverted. This is illustrated in Figure 6.

Figure 6

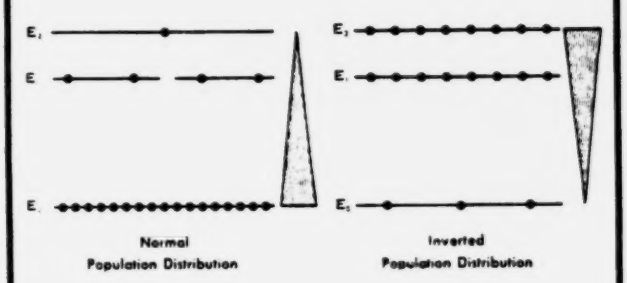


ILLUSTRATION OF POPULATION INVERSION

HOW DOES THE LASER OPERATE?

Now that some of the phenomena have been discussed, let us see how a laser is constructed and how it operates. Three components are necessary: (1) An active lasing medium, (2) an input energy source (called the "Pump"); and (3) an optical cavity.

(1) The Lasing Medium. Lasers can be classified according to the state of their lasing media. Four common families of lasers are presently recognized.

A. Solid State Lasers employ a lasing material distributed in a solid matrix. One example is the ruby laser, using a precise amount of chromium impurity distributed uniformly in a rod of crystalline aluminum oxide. The output of the ruby is primarily at a wavelength of 694.3 nm, which is deep red in color.

B. Gas Lasers use a gas or a mixture of gases within a glass tube. Common gas lasers include the Helium-Neon laser with a primary output of 632.8 nm and the CO_2 laser, with outputs in the blue and green regions are becoming quite common. Even water vapor can be made to yield a laser output in the infrared.

C. Liquid Lasers are relatively new and the lasing medium is usually a complex organic dye. The most striking feature of the liquid lasers is their "tunability". Proper choice of the dye and its concentration allows light production at almost any wavelength in or near the visible spectrum.

D. Semiconductor Lasers are not to be confused with solid state lasers. Semiconductor devices consist of two layers of semiconductor material sandwiched together. One material consists of an element with a surplus of electrons, the other with an electron deficit. Two outstanding characteristics of the semiconductor laser are its high efficiency and small size. Typical semiconductor lasers produce light in the red and infrared regions.

(2) Pumping Methods. Laser action can occur only when a population inversion has been established in the lasing medium. This population inversion can be established by pumping energy into the lasing medium. Several methods of pumping are commonly used. Optical pumping is employed in solid state and liquid lasers. A bright source of light is focused on the lasing medium. Those incident photons of correct energy are absorbed by the electrons of the lasing material and cause the latter to jump to a higher level. Xenon flashtubes similar to strobe lights used in photography, but more powerful, are commonly used as optical pumps for solid state lasers. Liquid lasers are usually pumped by a beam from a solid state laser.

Electron collision pumping is utilized in gas lasers. An electrical discharge is sent through the gas filled tube. The electrons of the discharge lose energy through collisons with gas atoms

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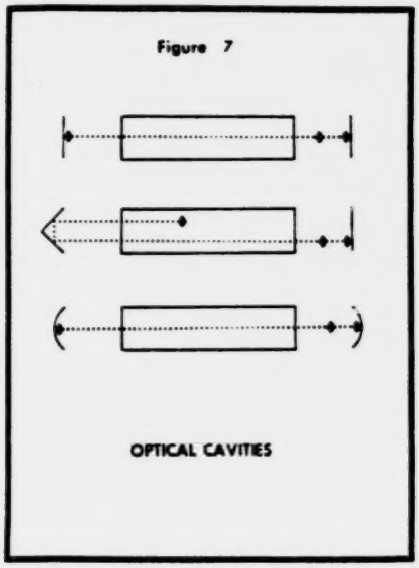
or molecules and the atoms or molecules that receive energy are excited. Electron collision pumping can be done continuously and can therefore lead to continuous laser output.

(3) Optical Cavities. Once the lasing medium has been pumped and a population inversion obtained, lasing action may begin. If, however, no control were placed over the direction of beam propagation, photon beams would be produced in all directions. This is called superradiant lasing.

The direction of beam propagation can be controlled by placing the lasing medium in an optical cavity formed by two reflectors facing each other along a central axis (Figure 7). Photon beams which are produced along the cavity axis are reflected 180^{o} at each reflection and travel once more through the lasing medium causing more stimulated emission. Thus, the beam grows in magnitude with each traverse of the lasing medium.

Figure 7

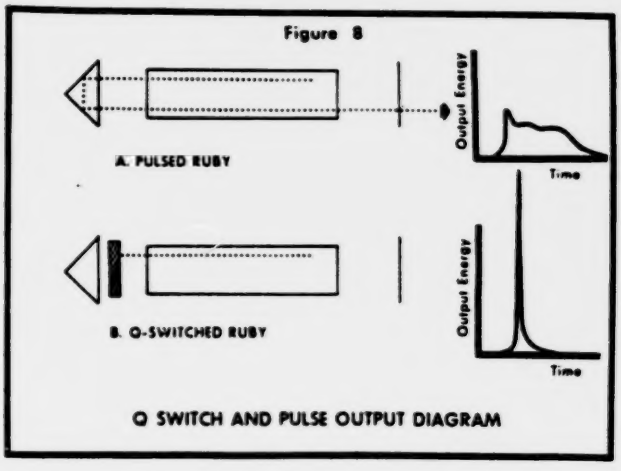


OPTICAL CAVITIES

Since the reflectors are not 100 percent reflective, some photons are lost by transmission through the mirrors with each passage. If the pumping is continuous, a state of equilibrium will soon be reached between the number of photons produced by atoms raised to the excited state and the number of photons emitted and lost. This results in a continuous laser output and is usually used only with low form power input levels. Higher power inputs usually are achieved in the form of a pulse, and the output is also in pulse form. One of the mirrors in the system is usually made more transparent than the other and the output, pulsed or continuous, is obtained through the reflector.

Q-switching (or Q-spoiling) is used to produce an exceptionally high-power output pulse. The term "Q" as applied to lasers is derived from the more familiar Q of electrical circuits. Lasers are resonant cavities and in a similar way, many electrical devices are resonant. The Q is a numerical index of the ability of the resonant cavity to store energy at the output frequency. The higher the Q, the more effective the power concentration at the resonant frequency. Q-switching in lasers refers to the method of laser operation in which the power of the laser is concentrated into a short burst of coherent radiation. A Q-switch is a device which interrupts the optical cavity for a short period of time during pumping. A schematic of a Q-switched solid state laser is shown in Figure 8.

Figure 8



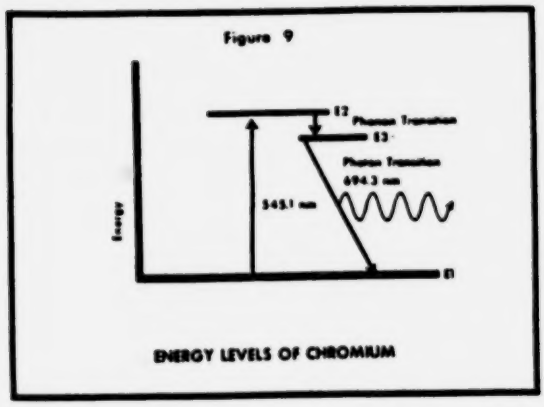
Q SWITCH AND PULSE OUTPUT DIAGRAM

Lasing action normally begins as soon as a population inversion is achieved and continues as long as pumping action maintains the inversion. The Q-switch interrupts the optical cavity and reduces the losses due to lasing until pumping can achieve a greater population inversion, say 70% to 80%, the Q-switch then suddenly restores the cavity and the resulting pulse is much shorter and more powerful than would normally be achieved.

One example of a Q-switch is the Pockel's cell, made of a crystal of ammonium or potassium dihydrogen phosphate (ADP or KDP) sandwiched between two crossed polarizers. In its de-energized state, the crystal will not affect polarized light. When an electric field is applied across the crystal, however, the plane of polarization of the incident light is rotated by 90°, allowing it to pass the second crossed polarizer. This completes the optical cavity and results in a giant pulse.

Reflectors may consist of plane mirrors, curved mirrors, or prisms, as shown in Figures 7 and 8. The mirror coating may be of silver if laser output power is low, but higher powers may require dichroic material. A dichroic material is a crystalline substance in which two preferred states of polarization of light may be propagated with different velocities and, more important, with different absorption. By appropriate choice of material and thickness, the light impinging upon the dichroic coating may be either totally absorbed or totally reflected. The first ruby lasers were constructed with the crystal ends polished optically flat and silvered. Semiconductor lasers use a similar technique. Gas lasers may use mirrors as seals for the ends of the gas tube or may utilize exterior mirrors. In the latter case, the tubes use end windows of glass or quartz set at Brewster's angle and the output is polarized light.

(4) The Ruby Laser. The laser first successfully operated was a ruby laser. It was constructed and operated by Dr. T. H. Maiman in 1960. Ruby is a crystal form of aluminum oxide with about 0.05% by weight chromium as an impurity. The chromium gives the ruby its red color and is responsible for the lasing. Chromium exhibits a 3-level energy system, as represented in Figure 9.



In a ruby laser, the electrons of chromium atoms are pumped to an excited energy level by means of an xenon flashlamp placed beside or around the ruby rod. The chromium electrons absorb photons in a band centered around 545.1 nm and are raised from their ground level to excited level E2. From here, they drop almost immediately to level E3 by means of a phonon (radiationless) transition. The small amount of energy lost here is through heat and vibration. The electrons will reside in level E3 for a considerable length of time--much less than a second--but for an electron that is a relatively long time. Thus, since the flashlamp operates in a period of microseconds, a population inversion can be obtained.

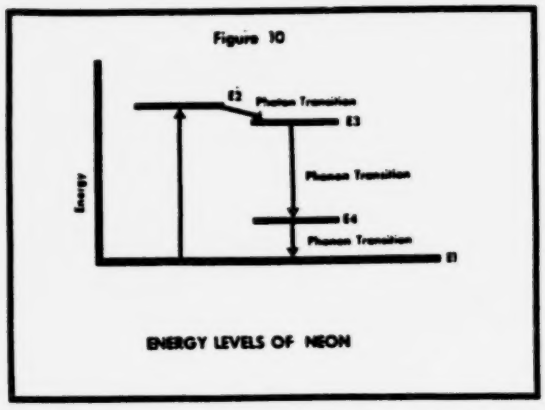
The excited atoms begin to de-excite spontaneously, dropping from level E3 to E1, and since a population inversion is in effect, stimulated emission may begin. In any lasing medium, stimulated emission may occur in all directions and no particular direction of propagation is favored. As stated earlier, to gain control of the emission direction and increase the amount of energy within the pulse, the lasing medium is placed within an optical cavity. Photons not emitted along the a[illegible] of the cavity will pass out of the system and be lost. If, however, a photon cascade is aligned with the cavity axis, it will encounter one of the mirrors and be reflected back upon itself, pass once more through the lasing medium and trigger more excited atoms to undergo stimulated emissions. The pulse thus grows in size and on each encounter with the less reflective mirror, part of it emerges from the laser as high intensity coherent light.

The pulse from a typical ruby laser lasts only a few microseconds, since the pumping is not continuous. The flashlamp is run by a charge stored in capacitor banks, and once the lamp has flashed, the capacitors must be recharged. Pumping occurs over

a few hundred microseconds and continues as long as the flashlamp is discharging.

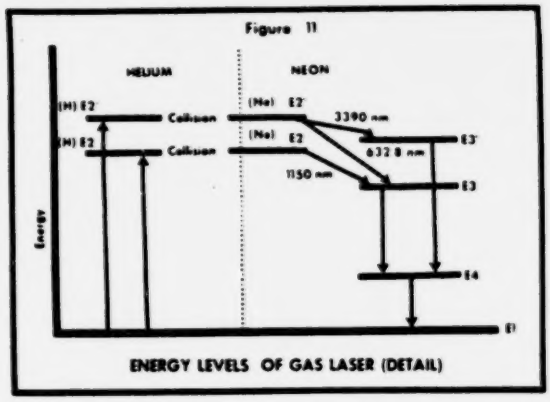
(5) The He-Ne Laser. The most common laser used today in both industry and education is the helium-neon laser. It was first operated in 1961 by Ali Javan and has proved to be the forerunner of a whole family of gas lasers. Since gas lasers are all quite similar in construction and behavior, we shall discuss the He-Ne laser as representative of the group.

The lasing medium in the He-Ne laser is a mixture of about 85% helium and 15% neon, with neon providing the lasing action. An energy level diagram for neon is shown in Figure 10.



The four-level system of a gas laser differs from the three-level system of chromium in that the emission of a photon does not return the atom to a ground level. Transitions from level E3 to E4 and E4 to E1 are accomplished through phonon transitions in which energy is transferred mainly through heat.

Pumping of neon to an excited state is not done directly by the energy source. Rather, indirect pumping is accomplished by exciting atoms of helium which then transfer energy to the new atoms by way of electron collision. These two gases are picked because they have electron excitation levels which are almost identical, thus facilitating the necessary energy transfer. Additionally, in the mixture of gases used, one does not need to affect a population inversion in helium in order to obtain a population inversion in neon. A more complete energy level scheme for He-Ne is shown in Figure 11.



The He-Ne gas mixture is contained in a sealed tube. Excitation of the helium is accomplished by a discharge of electricity through the tube, similar to a neon sign. The mirrors may be enclosed within the tube or may form the end caps of the tube containing the He-Ne mixture. This is a rather solid geometrical configuration and results in a stable light output.

Since the alignment of the mirrors is a delicate procedure, one common method is to mount the mirrors separate from the laser tube. When this is done, the ends of the laser tube are made of pyrex or quartz set at a Brewster's angle to the axis of the laser, and the output is polarized light.

(6) Other Lasers. Other lasers operate in similar but more complicated ways. Changes in molecular energy levels may be used rather than changes in electron energy levels, but output is still obtained through the stimulated emission of radiation.

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Learning Activity Packet

MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 5

LAP TITLE: Scattering of Light

PREREQUISITE LAP (S): 1, 2, 3 & 4

LAP PURPOSE: To view laser light due to small paricles such as dust, which scatter much of the light from the laser.

COMPETENCIES TO BE DEVELOPED:

1. To understand why light scatters from natural light.
2. To understand the scattering of a leser beam due to particle reflections.

SCATTERING OF LIGHT

Purpose

Laser light, like any other light, is invisible to our eyes unless it is traveling in a direction which will permit it to enter the eye and fall on the retina. When small particles, such as dust, are in the laser path, much of the light will be transmitted but some of it will be scattered by the small particles. This scattered light enables us to "see" the laser beam. It will be observed that whenever scattering occurs there will also be some absorption of the laser beam, and it will weaken in intensity as a result. Try some of the suggestions for scattering experiments given below. At this point, you may wish to design your own scattering experiments. In either case, take careful notes as you proceed.

Procedure

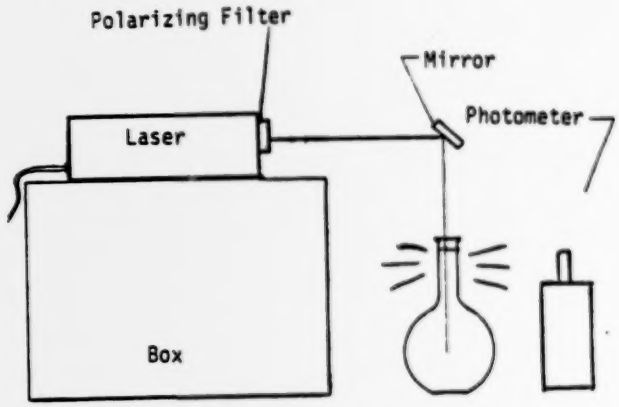
A. Shake chalk dust from a blackboard eraser in front of the laser and record the scattering effects that are observed.

B. Pour some water into a container and shine a laser beam through the water before the air bubbles have had time to leave. Record the scattering effects that are observed as the air bubbles rise and finally disappear.

C. Hold some clear ice in front of the laser beam and observe the scattering effects that occur when the beam encounters any imperfections in the crystalline structure.

D. Shine the laser beam through a tank of clear water and place a photometer on the far side of the tank to measure the output of the laser beam. Place measured amounts of various chemicals which do not dissolve in the water and stir each time a small quantity of chemical is mixed with the water. Make graphs to show the relationship between the concentration of chemical mixed with the water versus the reading of the light meter.

E. When light is scattered, it is not scattered uniformly in all directions. Using a suitable liquid solution or suspension, place the base of a protractor along the laser beam and observe the amount of light that is scattered at various angles with respect to the beam. If a light meter or photometer is available, take quantitative data and on a graph, plot the meter reading versus the scattering angle.



F. Observe Rayleigh scattering using the setup shown above. Put a few drops of $AuNO_3$ in a florence flask full of water. Polarize the laser beam by placing a polarizing filter over the front of the laser.

With the aid of a mirror, shine the laser beam along the axis of the flask neck and observe the intensity of the light scattered from the flask. With a photometer at a constant distance from the flask, move it in a 360° circle recording the intensity of the scattered light each 10° and plot the result on polar graph paper.

More complex scattering patterns result with a few drops of milk in the flask. Unlike AuNO , milk particles are much larger than the wavelength of laser light so the scattering pattern is not as simple as the Rayleigh, but it will be easy to observe by eye that the intensity of the scattered light is not uniform in intensity about the neck of the flask.

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Learning Activity Packet

MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 6

LAP TITLE: Laser Beam Divergence

PREREQUISITE LAP (S): 1, 2, 3, 4 & 5

LAP PURPOSE: To illustrate the negligible spreading of the laser beam.

COMPETENCIES TO BE DEVELOPED:

1. To know that the laser beam is collimated with very little beam divergence in diameter.

INTRODUCTION

One of the most useful characteristics of the laser beam is it possesses negligible divergence and thus can travel great distances with very little spreading. It is this quality (among others) of the laser beam that make possible laser beam communications between our earth and the moon. This demonstration will illustrate the negligible spreading of the laser beam.

Components Required:

LDS 10 Laser

Piece of White cardboard about 6" x 6"

Setup

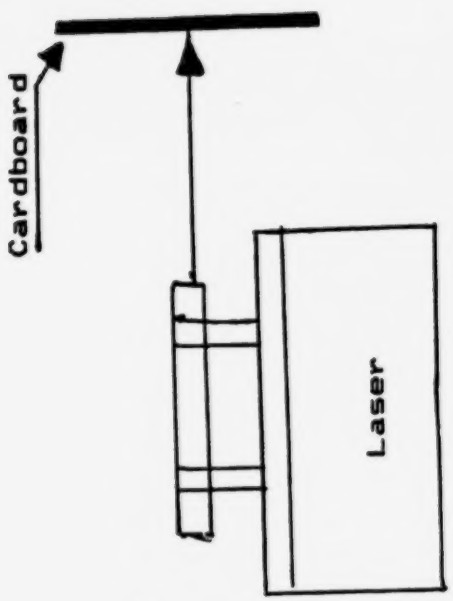
Be sure the laser is setup and mounted to its support on the side of the laser cabinent, as well as being turned on.

Next, place the white cardboard about a foot (12") away from the end of the laser.
Measure the diameter of the spot produced on the cardboard at this distance and record it.
Now move the cardboard about six feet away from the end of the laser and again measure the size of the spot of light and record it.
Try the same procedure again at twelve feet and record the answer.
If space permits, keep repeating the procedure at greater and greater distances.

Discussion:

From the previous demonstration, it can be seen that the laser beam possesses very little divergence over considerable distances. A similar diameter starting beam of ordinary light would possess much greater divergence and this is why lenses and other optical means must be used to focus and converge ordinary light.

Fig.7



- DIVERGENCE OF A LASER BEAM

Purpose

One of the chief advantages of a laser is that it produces a beam of light whose edges are parallel. Any deviation from perfect parallelism will eventually cause the beam to diverge and spread out its energy, becoming weaker and weaker with distance. Perfect parallelism, however, is an unobtainable goal which is difficult or even impossible to achieve under practical conditions. Each instrument is guaranteed by the manufacturer to produce a beam that is somewhere between perfect parallelism and a specified amount of divergence. In this experiment, we shall measure the actual divergence of our laser beam.

Procedure

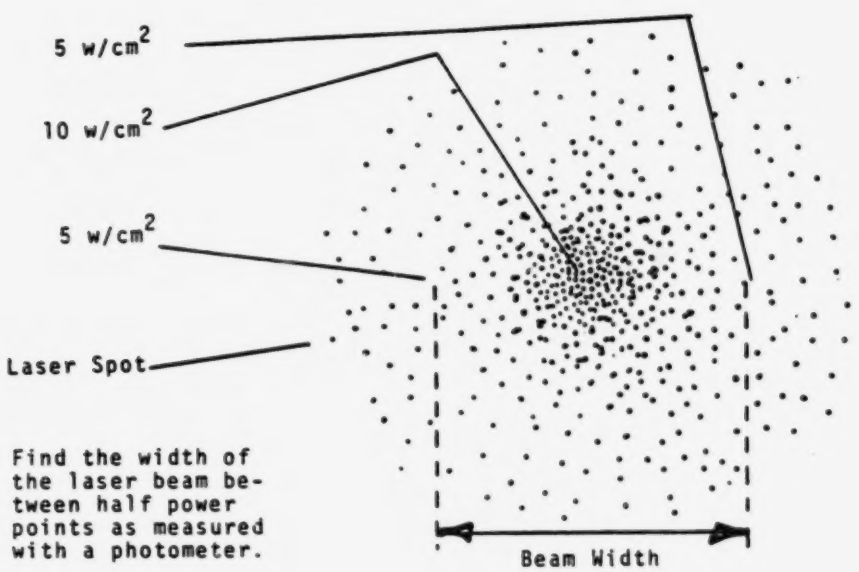
A. Measure the diameter of the laser beam by holding a sheet of millimeter graph paper in front of the laser. Record the diameter of the bright red spot on the graph paper.

B. At a distance of 10 meters in front of the laser, measure the diameter of the beam again using the same piece of graph paper. Using a long corridor, repeat this procedure at 10 meter intervals for the longest distance that is practical. Try this outdoors in broad daylight with the laser pointed along the ground in the general direction of the sun using a cardboard box to shield against the direct rays of the sun.

NOTE: The outer edge of the beam is fuzzy and it sometimes is difficult to tell where the beam ends. For consistency, use the half-power points for the edges of the beam. At these points, a photometer indicates that the beam is only one-half as intense as it is in the central portions of the beam.

C. Make a graph plotting the beam diameter versus distance and draw the best straight line connection to the points.

D. Calculate the angular divergence of the beam by dividing the change in beam diameter by the distance from the laser. The quotient will be the angle measured in radians. Multiply this value by 1000 to obtain the beam divergence angle in conventional units of milliradians.


5 w/cm²
10 w/cm²
5 w/cm²
Laser Spot
Find the width of the laser beam between half power points as measured with a photometer.
Beam Width

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MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 7

LAP TITLE: Measuring Beam Intensity

PREREQUISITE LAP (S): 1 - 6

LAP PURPOSE: To provide one with the knowledge that the laser is very intense and because it does not diverge - intensity does not decrease.

COMPETENCIES TO BE DEVELOPED:

1. To enable one to understand that the light intensity at various distances from the laser does not decrease significantly over distance.
2. To use a photometer in the measurement of laser beam intensity over incremental distances.

BEAM INTENSITY

Purpose

One of the chief advantages of a laser is that its primary beam is very intense and because the beam does not diverge much, the intensity does not fall off rapidly with distance. In this experiment, these characteristics of your laser will be measured.

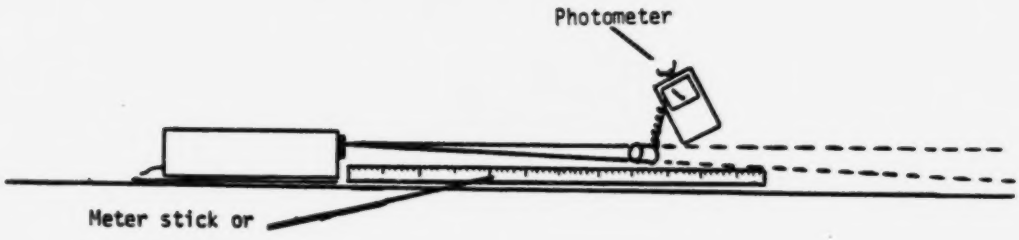
Procedure

A. Hold a sheet of glossy white paper in front of the laser and note the intensity of the red spot. Walk away from the laser for a distance of 100 meters or more while noting the beam intensity at one meter intervals.

CAUTION: Be careful not to look directly into the laser beam yourself and take precautions that the beam does not shine directly into the eyes of others in the immediate vicinity.

B. Measure the light intensity at various distances from the laser using a photometer.

C. Using a photometer, such as the one furnished with the Advanced Laser Optics Education Kit, measure the intensity of the beam at various distances from the aperture. Make sure that the opening which admits light into the photometer is the same width as the laser beam at its narrowest portion. For future reference, make a graph of the beam intensity versus distance. On the graph note the relevant experimental data such as the type and model light meter, the range setting, and the ambient light conditions.



Measure the light intensity at various distances from the laser using a photometer

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Learning Activity Packet

MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 8

LAP TITLE: Laser Beam Color

PREREQUISITE LAP (S): 1 - 5

LAP PURPOSE: Lasers of different types emit beams of varying wavelengths yielding a monchromatic colored light. The purpose of this experiment is to illustrate this concept.

COMPETENCIES TO BE DEVELOPED:

1. To understand a laser beam cannot be divided into colors.
2. To understand the effect of colored filters upon laser beam color.

Wavelength

Metrologic helium-neon lasers emit orange-red light at the 632.8 nanometer (10^{-9} meter) wavelength. The light is nearly monochromatic, a single color.

Procedure: Form a narrow beam of white light, perhaps by passing rays from the sun between two razor blades, and allow the beam to pass through a prism. A spectrum of colors will appear. Do the same with neon laser light. Since there are no other wavelengths except red present, the laser light cannot be divided into colors.

Discussion: To be precise, it must be stated that most lasers are not quite monochromatic. A truly monochromatic laser (a single frequency laser) would produce only one wavelength. Metrologic lasers produce a number of closely related wavelength frequencies (axial or longitudinal modes) spaced about 500 MHz apart. These axial modes are spaced within a bandwidth roughly 1.5 GHz wide.

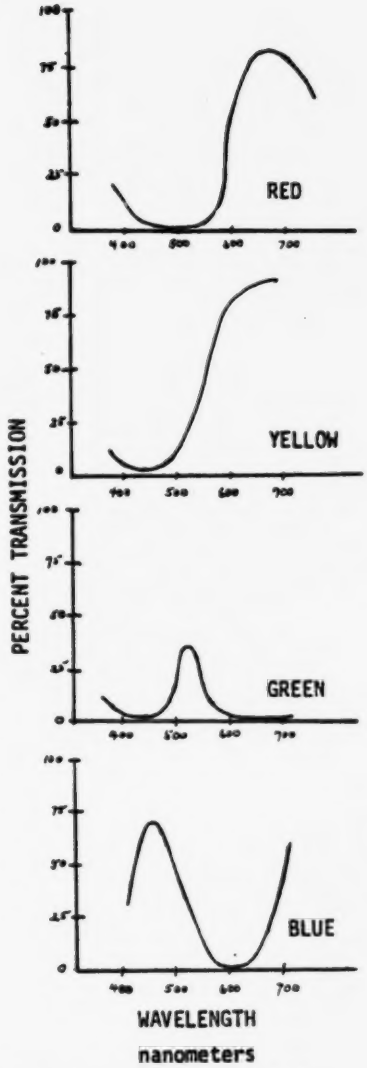
Absorption of light (white light)

Color filters absorb certain wavelengths, while allowing light of other wavelengths to pass relatively unaffected.

Procedure: Hold filters of various colors in front of your eyes and view objects in the room (not laser beams).

Discussion: Notice that objects appear dark or black (absence of light) when their color has been absorbed. During the absorption process, the light energy of the absorbed wavelengths is changed to heat or mechanical energy inside the filter.

Additional exercises: Try to determine the percentage of transmission of blue, green, yellow, orange, and red light through various color filters. Compare with the data in the figure.



Absorption of light (laser light)

Certain types of filters act strongly as absorbers of the red light of helium-neon lasers.

Procedure: Use a diverging lens to spread out the beam of a neon laser to a circle an inch or more in diameter. Hold various color filters in front of your eyes and view the beam. Select a filter which best absorbs the red light of the laser.

Discussion: Special green filters used on laser safety goggles attenuate helium-neon laser light more than a thousand times. Users of these goggles cannot see the beam. The reason a green pilot lamp is placed on the laser is to help a person wearing laser safety goggles find the ON/OFF switch in case the laser is being used in very dim lighting. The green of the pilot lamp is not absorbed by the safety goggles. (Metrologic does not recommend safety goggles for use with Class II lasers. Since the beam has such low power compared to other lasers no safety goggles are necessary.)

Coefficient of absorption

The thicker a filter, the greater the absorption.

Procedure: Find a homogeneous-colored glass which has several thicknesses. Shine a laser beam through each of the thicknesses and record the power output using a photometer. Plot the power output versus the thickness.

Discussion: The power output should vary in an exponential manner using the formula:

$$I = I_0 e^{-k(\upsilon)x}$$

For details refer to Beer-Lambert Law.

A laser tube is very much like a color filter in reverse. While a green or blue filter greatly attenuates the red light of a laser, the neon gas inside the laser tube amplifies red light. The entire laser tube is built as a very selective amplifier tuned to red light at the 632.8 nanometer wavelength. Allowing for technical exceptions, it is generally true that the longer the laser tube, the brighter the beam will be.

Color signal and noise

Using inexpensive color filters, it is relatively easy to separate the red laser light from the other wavelengths of "white" light.

Procedure: Find a color filter which transmits a high percentage of red light, but very little white light.

Discussion: Consider the bar code scanners used in supermarkets to decode the symbols on grocery packages. After the scanning beam crosses the symbol, the reflected light must find its way back into the scanner where it can be converted to electrical energy and then into a digital signal for input into a computer. Only a tiny portion of the original laser beam gets back to the photodetector. When it does, it must be clearly separated from room light. Actually, very inexpensive red color filters are commonly used. They allow 90% or more of the laser light to pass, while blocking 90% or more of the background white light. To the detector, the red light is bright and the background dark. For more critical applications, narrow bandwidth filters provide an even greater separation of signal and noise.

Reflection from opaque surfaces

Opaque materials selectively reflect wavelengths.

Procedure: Use a diverging lens to expand a laser beam to about one inch in diameter. Hold various colors of construction paper within the beam. Some will reflect the red laser light better than others. Sort the papers into colors which reflect a large amount of the laser light and those which absorb a large amount.

Discussion: Consider the color contrast problem of graphics designers who must plan the bar code symbols for grocery packages. If the designers want to print the bars using black ink, they must select a background color which will appear bright to the photodetector. The colors selected in the exercise above as high reflectors will appear bright to the detector and will probably make good backgrounds. The colors which were selected as high absorbers will appear dark to the detector and are not likely to be distinguished from the black bars.

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HIGH TECHNOLOGY MOBILE LABORATORY

Learning Activity Packet

MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 9

LAP TITLE: laser Ophtalmology

PREREQUISITE LAP (S): 1 - 5

LAP PURPOSE: To gain insight into the use of an expanded laser beam to illustrate diagnosis of eye defects.

COMPETENCIES TO BE DEVELOPED:

1. To know the proceudres in detecting far sightedness and near sightedness using the laser.
2. To explain the use of optics in the correction of eye defects.

LASER OPHTHALMOLOGY

Purpose

When an enlarged laser beam is aimed at a wall or at a piece of white paper, the illuminated area appears to have many small spots or grains. This granular appearance is caused by a complex interference pattern produced by the coherent light as the lens of our eye focuses it upon the retina. This phenomenon may be used to diagnose certain eye defects and illustrate how these defects may be corrected with the appropriate eyeglass lenses.

Procedure

A. In a room with subdued lighting, aim the laser beam at a piece of white paper 2 or 3 meters away. Expand the laser beam using the +15mm lens supplied with the Optics Education Kit.

B. Observe the illuminated area and notice the very many small dots or grains that appear. Move your head very slowly from side to side while observing the spot. If you are farsighted or if your eyes are normal, the small spots will appear to move in the same direction as your head. On the other hand, if you are nearsighted, the spots will appear to move in a direction opposite from that of your head movement. In nearsighted persons, the eye tends to focus the pattern a short distance in front of the retina. Therefore, the parallax caused by the head movement results in an apparent motion of the spots to the opposite direction.

C. Demonstrate the parallax described above by holding your fingers apart and placing them a few inches in front of your eyes while looking at an object on a distant wall. When your head is moved from side to side while looking at the distant object which represents the illuminated area, your fingers, which represent the granular interference pattern, will appear to move in the opposite direction.

D. Simulate myopia (nearsightedness) by holding the +80mm lens (part #45654 focal length 70mm or greater) in front of your eye. Observe the movement of the granulated spots as your head moves from side to side and record the results.

E. Simulate hyperopia (farsightedness) by observing the illuminated area on the wall through the -4mm lens. Observe the exaggerated movement of the granulations as they move in the same direction as your head from side to side.

F. If you normally wear eyeglasses, check your eyes in the manner described above with and without the corrective lenses recording your results.

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Learning Activity Packet

MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 10

LAP TITLE: Laser Reflections

PREREQUISITE LAP (S): 1 - 5

LAP PURPOSE: In this experimental investigation several types of laser beam reflections will be observed.

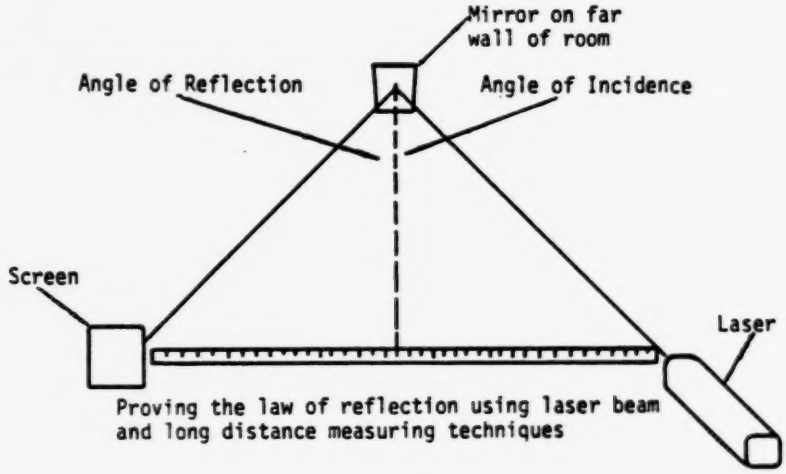
COMPETENCIES TO BE DEVELOPED:

1. To understand that when laser light comes to the boundary between two media having different optical densities, that a portion of the beam will be reflected.
2. To investigate the reflective characteristics of several kinds of materials.

LASER - REFLECTIONS

Purpose

Whenever light comes to the boundary between two media having different optical densities, some or all of the energy will be reflected. In this investigation several types of laser beam reflection will be investigated.



Proving the law of reflection using laser beam and long distance measuring techniques

Procedure

A. Types of Reflection

1. Investigate the reflective abilities of several different types of materials that are included in the Optics Education Kit. Materials such as flat mirrors provide specular reflection which changes the direction of the beam without scattering or diffusing the light. Rough objects such as unpolished metal, paper, or wood reflect the light at the same time as they scatter it. Point the laser beam at a variety of solids and liquids, and observe the light that is reflected by holding a piece of glossy paper near the object to catch the reflected light. In each case, record the type of material tested and the appearance of the reflected laser light.

2. Using a microscope slide or the specially designed beam splitter, investigate the phenomenon of partial reflection as part of a laser beam is transmitted through the material and part of it is reflected at the surface. Observe the relative intensity of the transmitted and reflected portions of the beam as the glass is tilted at various angles with respect to the incident beam. Record your observations.

3. Shine the beam into a tank of water and observe that reflections will take place not only when the beam enters the water, but also when the beam is leaving the water from a different side of the tank. Reflections that tend to keep the laser beam inside of a medium are known as internal reflections. The intensity of the internal reflection depends on the

angle that the beam makes with the surface. Set up an experiment to determine the relative amount of internal reflection as the angle between the laser beam and the surface is varied.

B. Law of Reflection The law of reflection states that the angle of incidence is equal to the angle of reflection and that the incident ray, normal and reflected ray all lie on the same plane. This may be verified with precision using the laser and the long distance techniques outlined below:

1. Place the laser on a table at the rear of a room and aim the beam at the center of the wall on the other side.

2. At the place on the wall where the beam appears, tape a flat mirror using masking or adhesive tape.

3. Mark around the point where the laser beam strikes the mirror using a fine felt tip pen.

4. Adjust the position of the laser so that the incident and reflected beams are superimposed and the reflected spot is as close to the laser aperture as possible. When this adjustment has been made, the laser beam coincides with the normal to the mirror surface. Mark the exact position of the laser at this time.

5. Move the laser three meters to the right of the original position in 50 cm steps. At each step, point the laser at the marked spot on the mirror at the far wall and see how far the reflected beam is to the left of the original laser position.

6. Examine the recorded data. According to the law of mirrors, the distance that the laser was moved to the right of its original position should be exactly the same as the distance that the reflected beam is to the left of that position.

7. Without touching the mirror on the far wall and with the laser slightly to the right of its original position, elevate the laser slightly by placing it on some books and point it at the marked spot on the mirror. Determine the relationship between the distance that the laser was elevated and the distance that the reflected beam is depressed.

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Learning Activity Packet

MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 11

LAP TITLE: Directivity of the Laser Communication System

PREREQUISITE LAP (S): 1 - 9

LAP PURPOSE: to demonstrate the characteristics of laser communications.

COMPETENCIES TO BE DEVELOPED:

1. To be able to explain the significance of the laser beam in directivity of laser communications.
2. To explain why any information that is on the laser beam cannot be detected or intercepted except by a laser placed directly in its path.

Introduction :

One of the most important characteristics of laser communication is its extreme directivity due to the narrow laser beam coupled with negligible spreading of the beam as it travels over considerable distances. In this Demonstration/Experiment, we will examine this characteristic in more detail.

Components Required :

LDS 10 Laser and Input Amplifier

Receiver

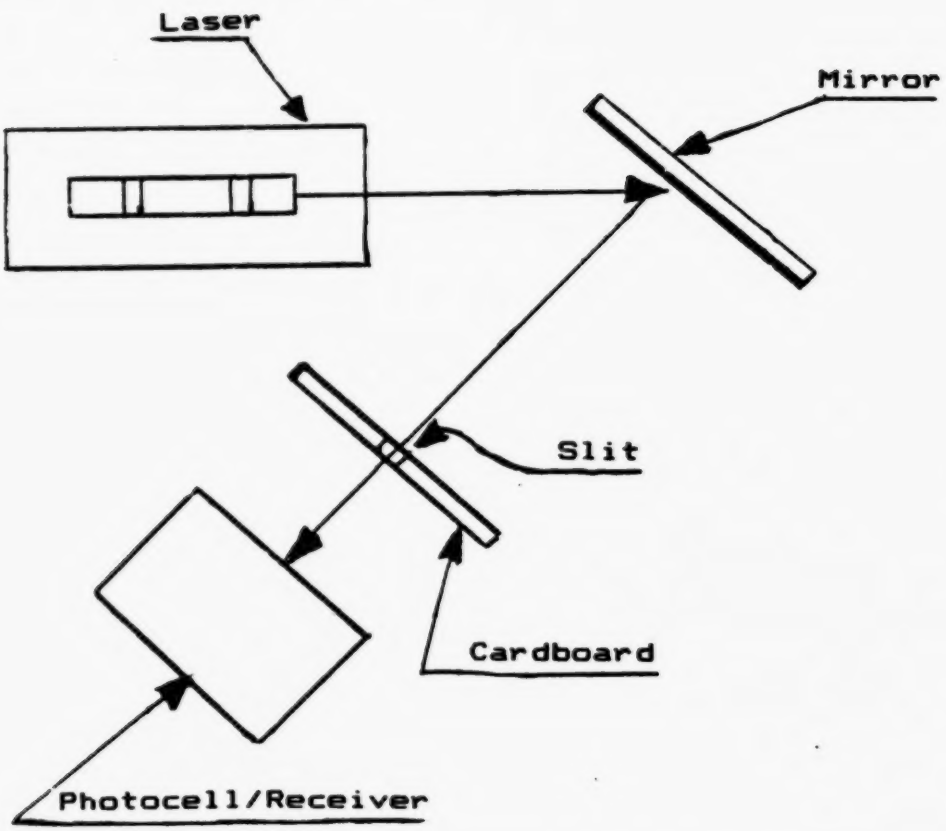
Mounted Mirror

4" x 4" White Cardboard

Setup :

To put the communications link in operation, connect the male RCA plug to the front panel and to the BNC to RCA adaptor furnished for the rear of the laser next to its on-off switch. Then aim the laser light at the grommet hole of the activated receiver and turn up both the volume controls on the receiver as well as the front panel laser control. A tone should be heard from the receiver along with some backround hum. Reposition the laser and/or receiver until the tone is clearly heard.

Fig.12



OPERATION :

Aim the laser so that it is pointed toward the center of the mirror as shown in the figure.

Make a 1/16" hole in the center of the cardboard square. Mount the cardboard so that the hole in it is roughly in line with the path the laser will take from the mirror to the laser receiver.

Keep the cardboard in place and position the mirror so that the laser beam is reflected from the mirror, through the hole in the cardboard and into the hole on the receiver which has the photocell.

At this point, the tone should be heard from the receiver. If not, readjust the mechanical and electrical setup until it is.

Once the tone is heard clearly, rotate the mirror to the right or left very slightly so that communication via the tone is lost. Any slight movement of the mirror stops the laser beam from passing through the hole in the cardboard, and thus it cannot strike the hole in the receiver and communication is indeed lost.

DISCUSSION :

From this demonstration it can be seen that in laser beam communication, the receiver photocell must be exactly on axis(head - on) for communication to take place. This characteristic is very desirable because it allows "exact" point to point communication. Any information that is on the laser beam cannot be detected or intercepted except by a laser placed directly in its path. This, together with the negligible spreading and high intensity of the laser beam, has made it attractive in military and high security applications.

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Learning Activity Packet

MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 12

LAP TITLE: Laser Beam Polarization Effects

PREREQUISITE LAP (S): 12

LAP PURPOSE: to demonstrate the effects of a polarizing filter on beam and wave vibrating perpendicular to the crystal structure of the filter.

COMPETENCIES TO BE DEVELOPED:

1. To note the effects of polarizing filter.
2. To observe the effects of a seond filter behind the first in light intensity.
3. To recongnize the use and function of the Brewster effect in laser use.

Introduction :

To demonstrate how it is possible to convey intelligence over a laser beam by means of polarization modulation.

Components Required :

LDS 10 Laser System and Input Amplifier

Receiver

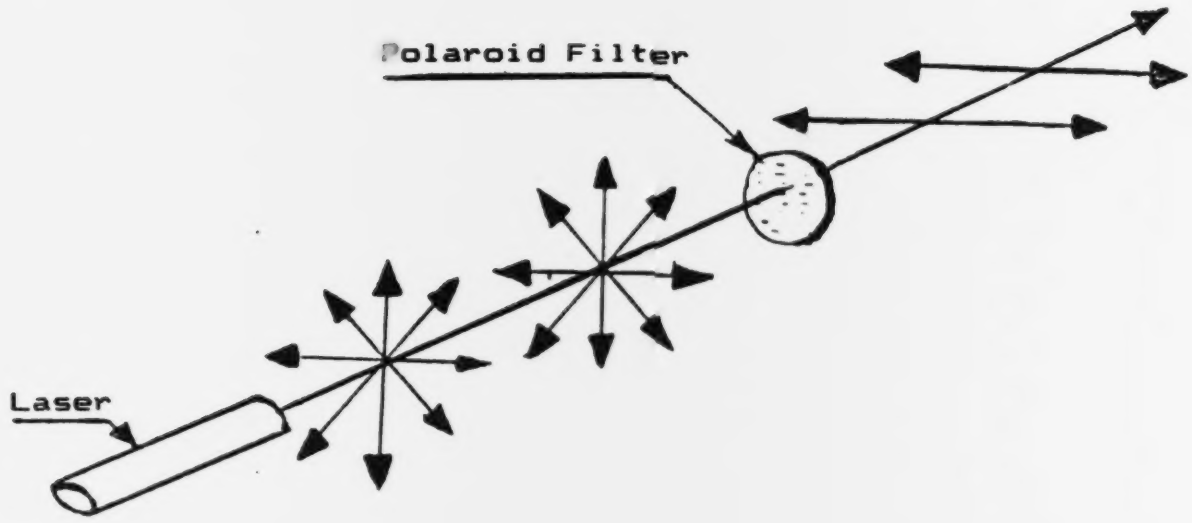
Piece of white cardboard 6" x 6"

Polaroid Filters - 2

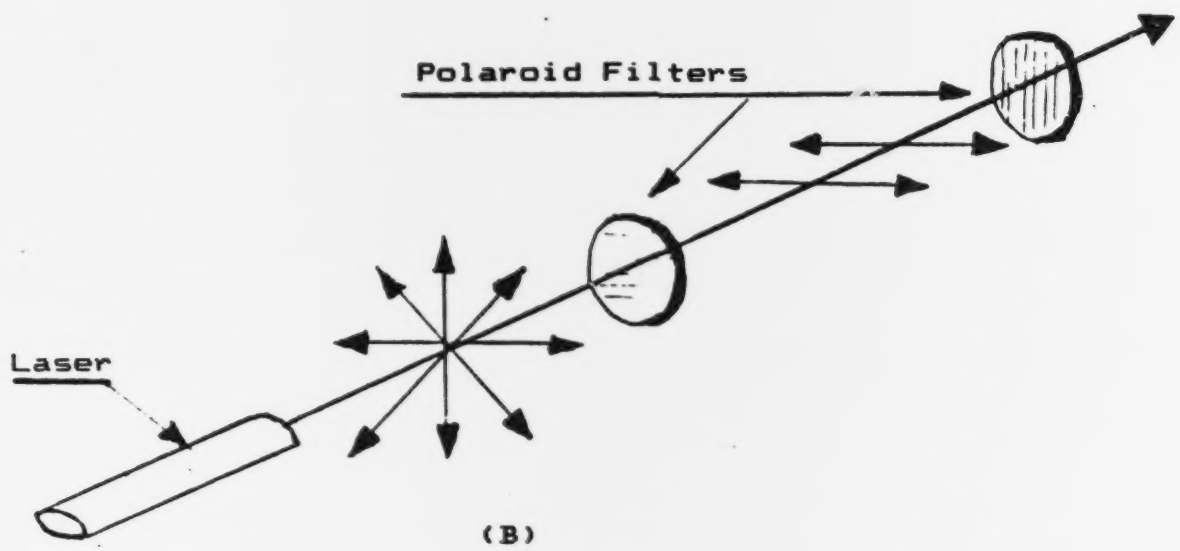
Operation :

Due to the characteristics of the LDS 10 laser, it is recommended that it be allowed to operate for about five minutes to come up to proper internal operating temperatures.

Take the two polaroid squares and place them in line with the laser beam using the appropriate holders so that one can be rotated with respect to the other. With one square stationary, slowly rotate the second filter. As you do so you will notice that the spot of red light from the laser projected on the cardboard will slowly dim and finally go out as the second square is rotated 90 degrees from the first.



(A)



(B)

The figure shows how this is accomplished. The light emitted by the laser is shown as radiated in many planes, as indicated by the arrows. When the beam passes through the first polarizing filter, all light is restricted or stopped, except that of a single plane of radiation.

When the second polarizing filter is placed next to the first filter and rotated to be at right angles (90 degrees) to the first filter as shown in the figure, the polaroid (single plane) light passing through the first filter will be blocked by the second filter. An easy way to understand the action of the filters is to visualize them as acting like electric venetian blinds. When the slats are parallel, light will pass through , but when the slats are at right angles to one another, most of the light is blocked.

Discussion :

While this demonstration serves to illustrate the principle of laser beam modulation, it is not practical to rotate the square filter by hand. In practical polarization modulation of the laser beam, a polarization device is used which automatically modulates the beam in step with an applied electric modulation signal. Such a device may be a piezoelectric crystal, which has the property of varying its polarization characteristics when an electric signal is applied.

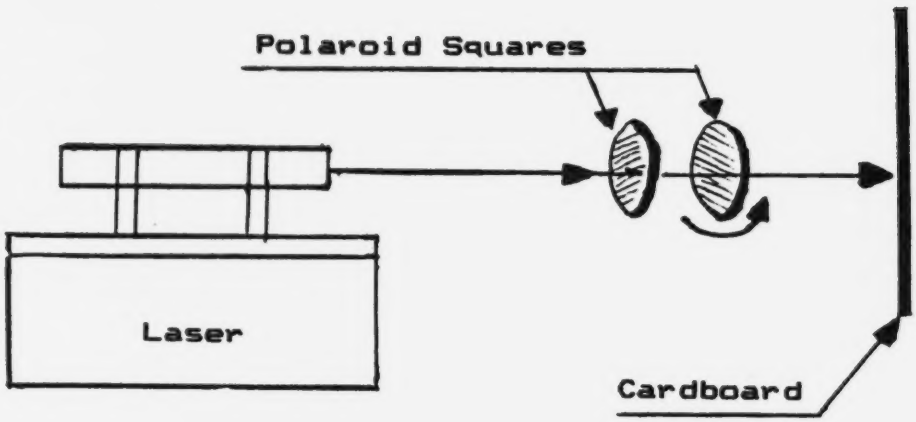


Fig.13

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Learning Activity Packet

MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 13

LAP TITLE: Measurement of Glass Thickness

PREREQUISITE LAP (S): 1 - 9

LAP PURPOSE: Is to demonstrate the use of the laser beam in precision measurement.

COMPETENCIES TO BE DEVELOPED:

1. To determine glass thickness by precise maser measurement.
2. To explain that no physical contact need be made of a glass object to determine its thickness.

Introduction :

One of the most important applications of the laser is in the field of precision measurements. By use of the laser beam it is possible to accurately measure the wall thickness of glass objects, such as plate glass. In this experiment we will see how it is done.

Components Required :

LDS Laser system

Mount and clear glass

Piece of white cardboard 6" x 6"

Setup :

Use the figure as a guide to set up the cardboard and the clear glass as shown.

Operation :

The glass should be in the laser beam so that the beam is reflected toward the cardboard. When the glass is properly positioned for this experiment, two light spots will be visible on the cardboard.

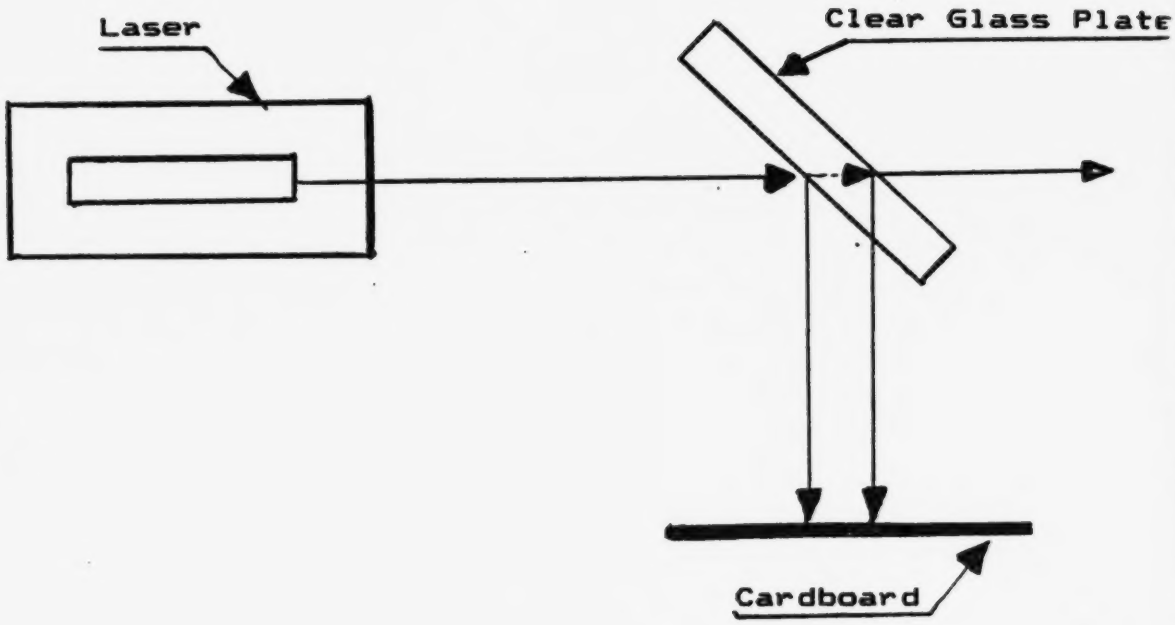
CAUTION :

A SECONDARY BEAM OF LIGHT WILL BE EMITTED FROM THE GLASS BECAUSE IT IS ACTING AS A BEAM SPLITTER. DO NOT LET THIS LIGHT STRIKE A PERSON OR ANIMAL IN THE EYES !!!!!

Discussion :

This glass thickness measurement technique offers a number of advantages over the use of more conventional glass thickness measurement techniques. As an example, the thickness of the interior parts of a complex glass object can be easily measured by this method. In addition, no physical contact need be made with the glass. The thickness of the glass is proportional to the distance or spread between the two beams we saw on the cardboard.

Fig.15



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Learning Activity Packet

MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 14

LAP TITLE: Measurement of liquid level

PREREQUISITE LAP (S): 1 - 10

LAP PURPOSE: This investigation will demonstrate graphically how the laser may be used to accurately detect liquid level in a container.

COMPETENCIES TO BE DEVELOPED:

1. To be able to explain how a laser beam may be used as a measurement of liquid level.
2. To be able to explain the use of reflecting mirror(s) to measure liquid levels.

Introduction :

This demonstration graphically illustrates how the laser can be employed as an accurate detector of the liquid level in a tank, or another container. A significant advantage of this method is that no foreign object such as a float need be placed in the liquid.

System Components Required :

LDS 10 Laser System

Receiver

Mount and mirror

Large Glass Beaker of Water (not supplied)

Setup :

To put the communications link in operation, connect the male RCA plug to the front panel and to the BNC to RCA adaptor furnished for the rear of the laser next to its on-off switch. Then aim the laser light at the grommet hole of the activated receiver and turn up both the volume control on the receiver as well as the front panel laser control. A tone should be heard from the receiver along with some backround hum. Reposition the laser and/or receiver until the tone is clearly heard.

Operation :

Due to the characteristics of the LDS 10 laser, it is recommended that it be allowed to operate for about five minutes to come up to proper internal operating temperatures, before modulation is applied.

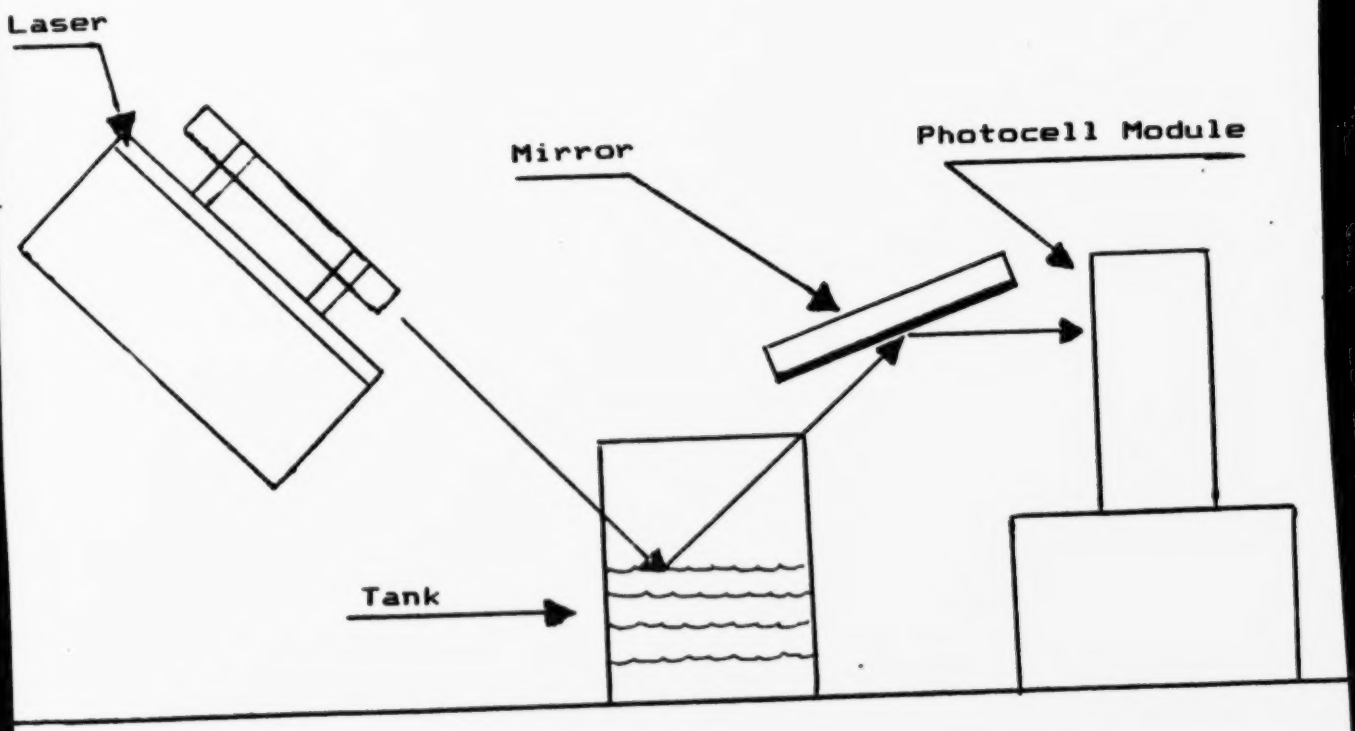

Fig.16

As shown in the figure, turn the laser in reverse on its mount so that it can be angled down to be aimed into the beaker of water (not supplied).

Position the mounted mirror so the beam reflected from the liquid will strike the photocell in the receiver grommet hole. It may be helpful to use a square of white cardboard to locate the beam properly also.

CAUTION :

A BEAM OF LIGHT WILL BE EMITTED FROM THE GLASS BEAKER OR MIRROR. DO NOT LET THIS LIGHT STRIKE A PERSON OR ANIMAL IN THE EYES!!!

The beaker should be partially filled with water.

When the laser beam is just above the water level, the tone should be heard clearly in the receiver.

Now add just enough water to break or scatter the laser beam.

You will note that the tone disappears, which indicates an increase in the water level.

Consider how to modify the present setup to tell when the water drops. Try it!

Discussion :

The figure shows the operation of the liquid level detector and we have just verified that when the beam is reflected back, we could determine if the water level dropped or increased. The next figure shows this graphically with the dotted lines.

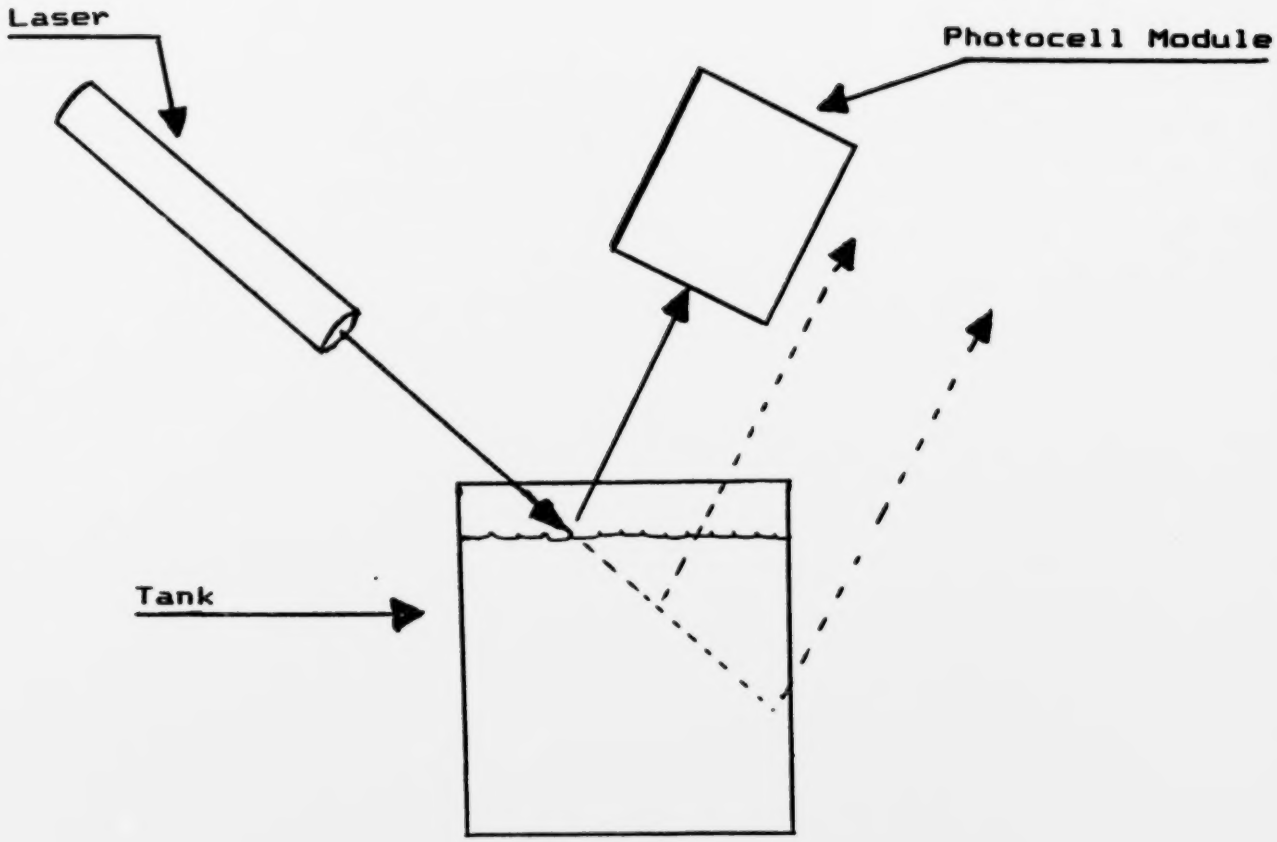

Fig.17

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Learning Activity Packet

MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 15

LAP TITLE: Laser Beam Intensity Control by Polarizers

PREREQUISITE LAP (S): 1 - 11

LAP PURPOSE: To demonstrate how polarizers may be employed to continuously vary the intensity of the laser beam.

COMPETENCIES TO BE DEVELOPED:

1. To sight several (3) practical applications of the use of polarizers to continuously vary the intensity of the laser beam.
2. To explain why it may be necessary to vary the intensity of the laser beam in construction and medical applictions.

Introduction :

In this demonstration, we will see how polarizers may be employed to continuously vary the intensity of the laser beam.

System Components Required :

LDS 10 Laser System

Receiver

White Cardboard - 6" x 6"

Two Polarizer Filters and Mount

Setup :

To put the communications link in operation, connect the male RCA plug to the front panel and to the BNC to RCA adaptor furnished for the rear of the laser next to its on-off switch. Then aim the laser light at the grommet hole of the activated receiver and turn up both the volume control on the receiver as well as the front panel laser control. A tone should be heard from the receiver along with some backround hum. Reposition the laser and/or receiver until the tone is clearly heard.

Operation :

Place cardboard approximately one foot away from the laser beam.

As shown in the figure, mount one polaroid filter so it is fixed in the laser beam. Rotate the second filter slowly and observe the beam intensity where it strikes the cardboard. The beam should dim and then grow bright again. Be sure the laser is warmed up and stable for about five minutes.

Repeat the experiment using the tone generator to indicate how strong the beam is.

Discussion :

The use of polarizers to continuously vary the intensity of the laser beam has a number of practical applications. For example, in the alignment of construction elements, it is often desirable to plot the course of the laser beam, but at a reduced intensity. The polaroid filters can be used to accomplish this.

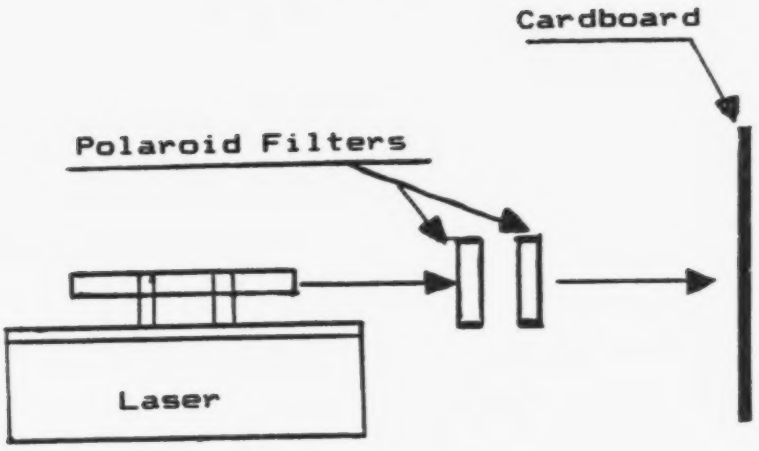

Fig.18

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Learning Activity Packet

MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 16

LAP TITLE: Splitting of the Laser Beam into Differing Paths

PREREQUISITE LAP (S): 1 - 12 and 15

LAP PURPOSE: To demonstrate how a laser beam may be split into two component parts.

COMPETENCIES TO BE DEVELOPED:

1. Explain how a laser beam may be split into components parts.
2. Give reasons (2) why beam splitting may be desireable.

Introduction :

In many instances, it is desirable to split the beam from the laser into two component parts. Such requirements are in the area of certain measurement techniques, holography, etc.

System Components Required:

LDS Laser System

Angle Support

Plain Glass Plate and Mount

Two pieces of white cardboard 6" x 6"

Setup :

Mount the laser on the angle mount.

Mount the plane glass plate as shown in the figure.

Place the two pieces of cardboard as shown.

Operation :

Orient the mounted glass plate until three distinct beams are produced: one on the cardboard which is directly in line with the laser beam output, and two beams which are at right angles to the laser..

Discussion :

The splitting action of the plain glass is due to the beam being reflected from the surfaces of the glass. Two beams are produced a t right angles to the original beam due to reflection from the front and back surfaces of the glass. The third beam results from the original beam passing directly through the glass.

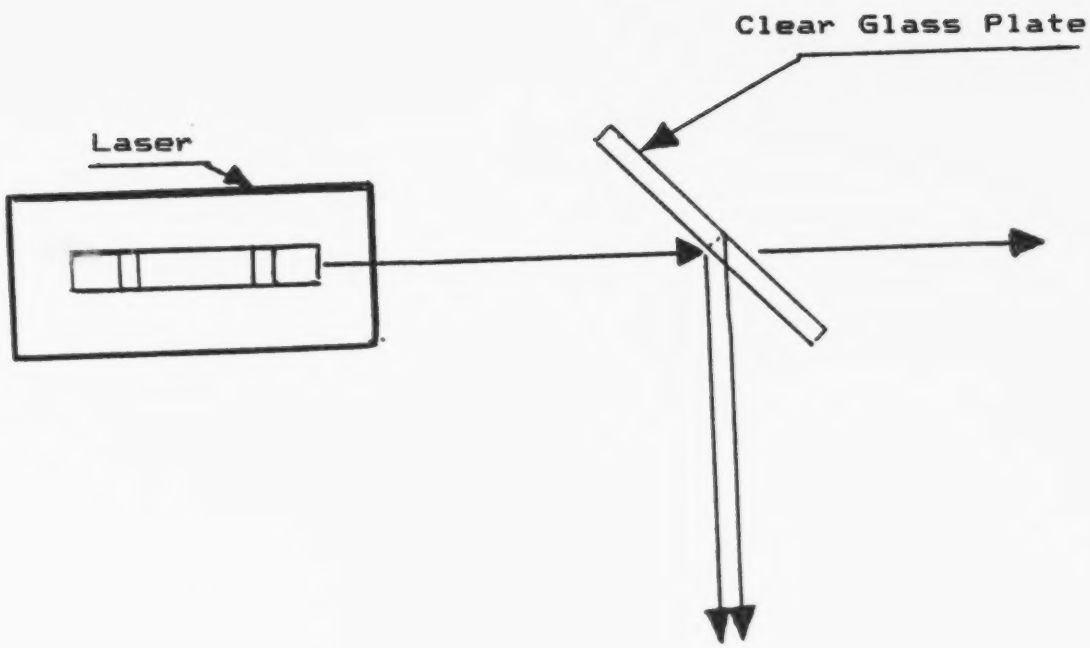

Fig.20

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Learning Activity Packet

MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 17

LAP TITLE: Laser Beam Splitting by Prism

PREREQUISITE LAP (S): 1 - 8 and 15 - 16

LAP PURPOSE: To demonstrate the use of a prism to split the laser beam into two or more differing paths.

COMPETENCIES TO BE DEVELOPED:

1. Explain why there is a minimum light intensity loss when a beam is split into several paths.
2. Explain the basic principle of operation in the splitting process.

Introduction :

A prism may be employed to split the laser into two or more differing paths as will be seen in this demonstration.

System Components Required :

LDS 10 Laser System

Prism

Angle Support

Two Pieces of White Cardboard 6" x 6"

Setup :

Mount the LDS 10 laser on the angle mount and connect power.

Position the prism and two pieces of cardboard as shown in the figure.

Operation :

Note that two beams are produced as indicated in the figure. Rotate the prism on its axis to shift the position of the output beams.

Discussion :

The prism is employed as a beam splitter in applications requiring minimum light intensity loss in the splitting process. The basic principle of operation is the same as that of the glass (clear) beam splitter described in the previous experiment.

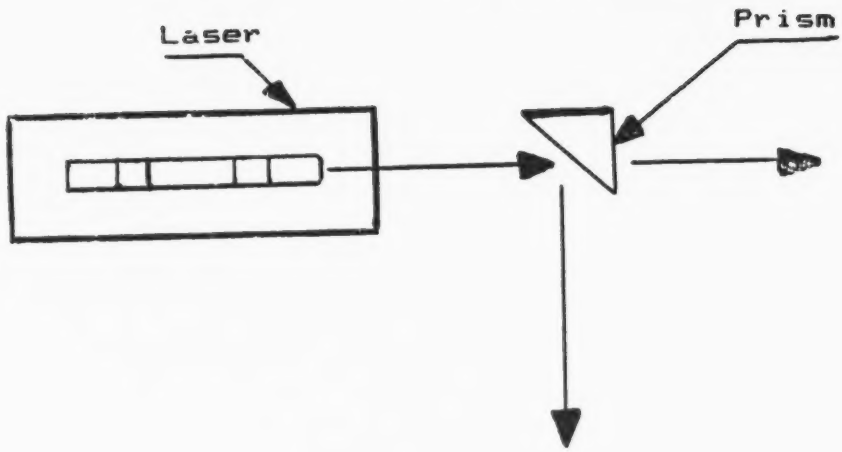

Fig.21

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Learning Activity Packet

MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 18

LAP TITLE: Light Pipes & Fiber Optics

PREREQUISITE LAP (S): 1 - 7 and 15 - 17

LAP PURPOSE: To demonstrate that as light is being transmitted through a fiber optic or water stream having a relatively high index of refraction, the light is internally reflected each time it attempts to leave the boundaries at a large angle of incidence.

COMPETENCIES TO BE DEVELOPED:

1. To explain the principle of reflectance in a media which confines light to its boundaries.
2. Discuss the differences between the effect of solids and liquids.

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DEPARTMENT OF INDUSTRIAL TECHNOLOGY

HIGH TECHNOLOGY MOBILE LABORATORY

Learning Activity Packet

MAJOR INSTRUCTIONAL UNIT LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 18

LAP TITLE: Light Pipes and Fiber Optics

PREREQUISITE LAP(S): #'s 1-7 and 15-17

LAP PURPOSE: To demonstrate that as light is being transmitted through a fiber optic or water stream having a relatively high index of refraction, the light is internally reflected each time it attempts to leave the boundaries at a large angle of incidence.

COMPETENCIES TO BE DEVELOPED:

1. To explain the principle of reflectance in a media which confines light to its boundaries.
2. Discuss the differences between the effect of solids and liquids.

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MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 19

LAP TITLE: Laser's Amplitude Modulated Communication

PREREQUISITE LAP (S): 1 - 6 and 15 - 18

LAP PURPOSE: To demonstrate an exciting and important application of the continuous output gas laser.

COMPETENCIES TO BE DEVELOPED:

1. Explain how the intensity of the laser is varied in accordance with sound variations picked up by a microphone.
2. Explain the function of the photocell as a receiver when the amplified signal is fed into a speaker to sound signal we can hear.

LASER'S AMPLITUDE MODULATED COMMUNICATION

One of the most important and exciting applications of the coniinuous output gas laser is in the field of communication. Due to the extremely wide frequency bandwidth of the laser beam (several thousand megahertz), it is possible to simultaneously transmit a number of TV channels, radio and telephone channels over a single laser beam. Due to the intensity of the laser beam, coupled with its wide bandwidth, laser beam communication will find a wide application in space age communications: both on earth and in outer space.
This particular experiment/ demonstration will show amplitude modulation of the laser beam.

Components Required :

LDS 10 Laser

LDS 10 Laser Receiver

Microphone

Interconnecting Cables

Setup :

Due to the characteristics of the LDS 10 laser, it is recommended that it be allowed to operate for about five minutes to come up to proper internal operating temperatures, before modulation is applied.

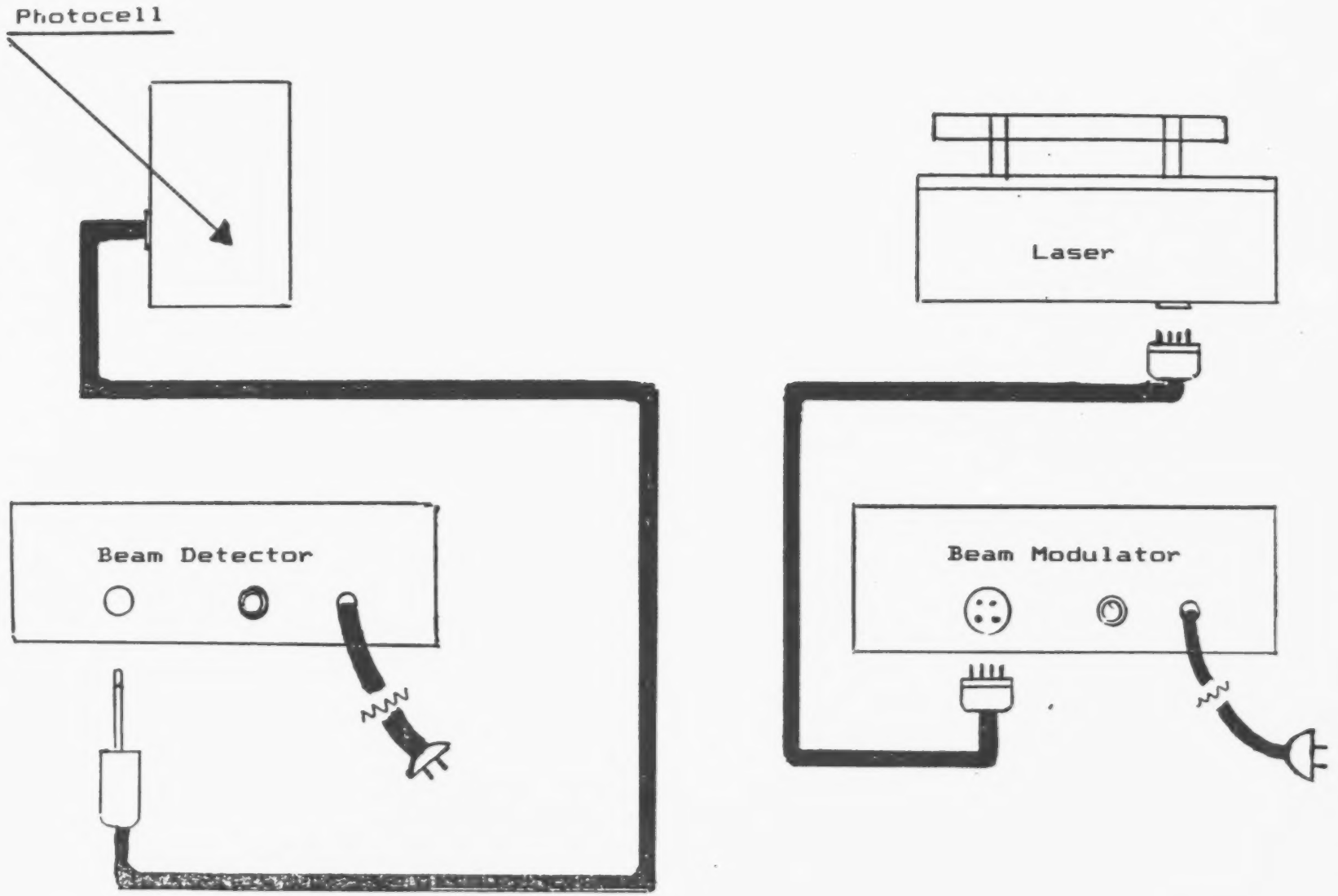

Fig.11

Operation

To put the communications link in operation, connect the male RCA plug to the front panel and to the BNC to RCA adaptor furnished for the rear of the laser next to its on-off switch. Then aim the laser light at the grommet hole of the activated receiver and turn up both the volume controls on the receiver as well as the front panel laser control. A tone should be heard from the receiver along with some backround hum. Reposition the laser and/or receiver until the tone is clearly heard.

Once the laser is On and warmed up and the communications link using the tone is in operation, plug in the microphone to the front panel and adjust the gain to eliminate any feedback and still have a clear sound when the microphone is spoken into. If necessary, reread the cautions given earlier about hum and outside light interference.

Discussion :

The laser beam modulation system utilizes amplitude modulation of the laser beam. By this we mean that the intensity of the laser beam is varied in accordance with the sound variations picked up by the microphone.

Specifically, sounds picked up by the microphone are converted into corressponding electrical signals by the microphone. This signal is applied to the amplifier contained in the front panel of the LDS 10 unit, where it is amplified and sent via the RCA cable to the connection at the rear of the actual laser unit.

In the laser, electronic circuitry converts the varying electrical signal that was produced by the microphone and amplified by the amplifier into an electrical signal which varies the intensity of the laser beam. We cannot see this variation, but it is present and it is the mechanism that enables us to transmit signals over the laser beam.

At the LDS 10 receiver, the varying laser beam is detected by the photocell and again amplified by an internal amplifier in the receiver. This amplified signal is fed to the small speaker in the receiver where it is converted to sound signals we can hear.

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MAJOR INSTRUCTIONAL UNIT: LASER

LEARNING ACTIVITY PACKET (LAP) NUMBER: 20

LAP TITLE: Simultaneous Amplitude and Polarization Modulation of the Laser Beam

PREREQUISITE LAP (S): 1 - 5 and 15 - 19

LAP PURPOSE: Is to show how the laser beam may be simultaneously amplitude and polarization modulated.

COMPETENCIES TO BE DEVELOPED:

1. To explain how to effectively transmit two different types of communication over a single laser beam.

Introduction :

The purpose of this Demonstration/Experiment is to show how the laser beam may be simultaneously amplitude and polarization modulated.

Setup :

To put the communications link in operation, connect the male RCA plug to the front panel and to the BNC to RCA adaptor furnished for the rear of the laser next to its on-off switch. Then aim the laser light at the grommet hole of the activated receiver and turn up both the volume control on the receiver as well as the front panel laser control. A tone should be heard from the receiver along with some backround hum. Reposition the laser and/or receiver until the tone is clearly heard.

Operation :

Due to the characteristics of the LDS 10 laser, it is recommended that it be allowed to operate for about five minutes to come up to proper internal operating temperatures, before modulation is applied.

As in the previous experiment, put the polarizing filters in line with the laser beam.

Rotate one of the filters and note that the intensity of the tone varies in step with the rotation of the one disc.

If you wish, plug in the microphone and try the rotation again.

Discussion :

This demonstration shows that it is possible to effectively transmit two different types of communication over a single laser beam. As mentioned in the previous demonstration, in practical applications the square would be replaced by a suitably excited crystal.